THE EFFECTS OF SOIL AMENDMENTS ON THE PHYSICAL STRUCTURE OF SOLODIZED SOLONETZ SOILS UNDER IRRIGATION

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ABSTRACT

Experimental plots were laid out at Youngstown in 1952 to determine the effects of certain soil amendments and cultural practices on the physical structure of solodized solonetz soils under irrigation. The treatments used were: sulphur, gypsum, krilium, manure and deep cultivation, and these were compared with an irrigated check and a dry check treatment.

Field studies included grain height measurements, yield data, and penetrometer data. Laboratory investigations consisted of mechanical analyses, aggregate analyses, soluble salt content, permeability and porosity measurements and nitrogen determinations.

Field and laboratory studies showed a large variation in physical and chemical properties both within and between the plots. These variations masked treatment effects during the first year, and the plots are still too young to draw conclusive results. Penetrometer data did provide useful information on the physical properties of the soil as affected by treatments. June and September penetrometer data were compared as well as the hardness of surface soil. In 1953 the sulphur, manure and gypsum treatments did significantly improve crop yields but only gypsum, sulphur and krilium improved the physical structure of the soil.

THE UNIVERSITY OF ALBERTA

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INTRODUCTION

Irrigation experience shows that there have been many successes and many failures. Scofield (47) affirms that the largest number of failures in irrigation agriculture has been due to unfavourable conditions of soil, water supply and drainage, not realized in advance. Irrigation projects would stand the best chance of success when all the physical factors are known and are carefully weighed on the economic balance before construction is begun. Successful irrigation projects have certainly transformed the productivity and economy of many parts of the world with far reaching beneficial effects; unsuccessful projects have left many communities and states burdened with debt, lowered standards of living and disrupted community facilities.

The proposed Red Deer river diversion irrigation project, or as it is sometimes termed, the Wm. Pearce irrigation project is designed to irrigate a semi-arid area north and south of Youngstown in south-eastern Alberta (see Plate I).

Several survey parties have covered the area. Wyatt and Newton (64) in their soil survey report of the Sounding Creek sheet described the area and discussed the predominance of the "blow out" phase loam in the now proposed irrigation area. Odynsky (37) outlined the solonetz areas in Alberta. It will be observed (see Plate I) that a large portion of the

proposed project is in his solonetz belt. Preliminary irrigation surveys have been completed by Prairie Farm Rehabilitation Administration engineers and the area of land that can be irrigated by gravity and by pump has been determined. The Alberta Soil Survey has recently completed a semi-detailed soil survey of the proposed irrigation project. Their survey indicates that approximately fifty per cent of the irrigable soil is classified as solodized solonetz.

While solodized solonetz soils occur in other irrigated areas, the geological formations underlying the glacial till differ. The permanence of the proposed irrigation project may well depend on the behaviour of the solodized solonetz under the particular conditions to be found in the proposed project. Some solodized solonetz soils in Alberta are under irrigation, especially in the vicinity of Brooks (see Plate I). Irrigation reclamation is apparently successful in that area due mainly to a permeable underlying C horizon. However, as Odynsky (op. cit.) points out, it is unwise to assume on the basis of the success in the Brooks area that all solodized solonetz soils are suitable for irrigation.

Recognizing the problems associated with the irrigation and improvement of solodized solonetz soils, the authorities in charge felt that an investigation of these soils was essential before construction of the project was commenced. The Research Council of Alberta and the Soils

Department, University of Alberta in co-operation with the Dominion Experimental Station, Lethbridge commenced experimental plots in 1952 near Youngstown. These experimental plots were designed to study methods and practices of irrigating and improving solodized solonetz soils. This thesis is a report on the effects of soil amendments on the physical structure of the solodized solonetz soils under irrigation at the Youngstown plots.

REVIEW OF LITERATURE

The Origin and Nature of Solodized Solonetz Soils

Lyon and Buckman (32) Pettijohn (38), as well as many other writers of texts in soil science and geology discuss the many sources of soluble salts. The direct source of salt constituents is the primary minerals found in soils and in exposed rocks of the earth's crust from which soil material is formed. During the process of weathering, salt constituents are gradually released and dissolved by water. The ocean may be considered as the source of salts as in the case where a soil's parent material consists of marine deposits which were laid down during earlier geologic periods. Water acts as a carrier for salts, and saline soils generally occur therefore in areas which are the recipients of salts brought in by ground water, drainage water, or irrigation.

A clear concept of the terms saline, alkali, solonchak, solonetz and soloth is important. The terms saline and alkali are generally used in literature to indicate the soluble salts and the degree of alkalinity in soils. The Riverside Salinity Laboratory (40) defines saline and alkali soils on the basis of the conductivity of a saturation extract and the exchangeable sodium percentage. The terms solonchak, solonetz, and soloth,

according to the U.S.D.A. Soil Survey Manual (53) refer to genetic groups of soils. Differentiation is based primarily on morphology and genesis.

The processes involved in the formation of saline and alkali soils as discussed by Byers et al (6) are: salinization, desalinization, alkalization and dealkalization and these will be reviewed briefly at this point.

Salinization:-- denotes the process of salt accumulation in soils. This process can occur on practically any kind of soil and gives rise to the development of saline soils - sometimes called solonchak. The accumulation of soluble salts, according to Richards (40) is due mainly to an arid climate, poor drainage and irrigation. Russell (44) explains how the high evaporation rates and low rainfall of an arid climate are responsible for localized patches of efflorescence on the surface of saline soils. Poor drainage is due to the presence of impermeable layers which restrict water movement. Richards states that these impermeable layers may be due to a clay pan, a caliche layer or a silica hardpan. A saline soil may be produced by the addition of salts to a non-saline soil. Richards, Chang (8) and Russell (op. cit.) explain how salinization of a soil may be caused by irrigation due mainly to special features of topography, high amounts of salts in irrigation waters and the failure to recognize the need for establishing artificial drainage.

Solonchaks are sometimes called "structureless" soils and lack prismatic and blocky structure. The term, solonchak, is also modified by the name of the dominant salt present. The U.S.D.A. Soil Survey Manual (op. cit.) states that if a solonchak has calcium as the dominant salt, it is called a calcium solonchak. With improved drainage and removal of salts the calcium solonchak gradually changes over to a normal soil while the sodium solonchak may change to a solonetz or a solodized solonetz and perhaps to a soloth before developing into a zonal soil.

Saline soils usually have a favourable structure and are readily permeable to water and air. This favourable condition is due to the presence of excess salts and the absence of appreciable amounts of sodium on the exchange complex which flocculates the colloids.

<u>Desalinization and alkalization</u> -- involves the removal of salts and the entrance of sodium into the base exchange complex. Strongly alkaline soils are formed as a result of the hydrolyzing of the sodium clays. This results in a deflocculation of the soil colloids. The eluviation of the clay follows deflocculation resulting in the formation of a very hard prismatic or columnar B horizon. This process is sometimes called "solonization" and the resulting soil is called a solonetz.

<u>Dealkalization</u> -- is the process in which the excess sodium of a solonetz is gradually removed by leaching. The upper part of the soil may become somewhat acid with a deep grey layer over an acid blocky B horizon. Such soils are called soloth and the process of change of solonetz to soloth is termed "solodization".

There are many differences of opinions among soil scientists the world over regarding the genesis and classification of saline and alkali soils. These differences of opinions are mainly the result of different concepts of the essential characteristics of solonetz as described by Russian scientists. Glinka (18) has taken the view that the solonetz is distinguished by certain morphological features and that the possessing of certain chemical characteristics is secondary. De Sigmond (11) postulated that the solonetz should have not less than ten to fifteen per cent of its base exchange capacity taken up by sodium. The papers of MacGregor and Wyatt (34) Riecken and Stalwick (42) and Bentley (4) all refer to soils having solonetz or solodized solonetz characteristics in which sodium does not dominate the base exchange complex. Russell (op. cit.) maintains that the B horizon of the solonetz is probably more indicative of the clay mineral than of exchangeable sodium or magnesium. Recent work mentioned by Grim (20) indicates that illite and montmorillonite are the dominant clay minerals of solonetz soils, no kaolinite being found as a rule.

Definitions of solonetz, solodized solonetz and soloth have been proposed. Bentley (op. cit.) states that the distinguishing feature between solonetz and solodized solonetz is given as the greyish, leached, platy structured, acidic A_2 horizon which is found in the latter but not in the former. He proposes that they be distinguished as follows: that the solonetz has less than six inches of A horizon above a columnar B horizon while the solodized solonetz has an A horizon of more than six inches. The U.S.D.A. Soil Survey Manual (op. cit.) states that soloth soils are uncommon while the intergrade soils called the solodized solonetz are common. These soils have the leached A horizon of the soloth and the non-acid columnar B horizon of the solonetz. The manual also states that a solonetz with neither excess salts in the solum nor suggestion of solodization in the A horizon is rare. A soil may go from a solonchak to a solodized solonetz without ever being a typical solonetz.

Solodized Solonetz in South Eastern Alberta

The Alberta Soil Survey have classified solodized solonetz soils on the basis of U.S.D.A. Soil Survey Manual definitions (op. cit.). The following is a generalized description of a Hemaruka loam (brown solodized solonetz) taken from Alberta Soil Survey files:-

Inches			pH
3 - 6	A_1	loose brown loam.	7.5 - 5.6
1/2 - 1 1/2	A_2	loose brown loam, mildly platy	7.1 - 6.5
5 - 10	B_2	very dark clay. Columnar with round or flat tops.	7.5
4 - 8	B_3	low to medium lime concentrations	7.5
SO_4 (salt) at 25"		variable concentration	8.0
C at average 30"		a heavy textured till containing chunks of coal, ironstone and shale fragments.	

Solodized solonetz soils have noticeable distinguishing features. The A horizons are variable in depth; the B horizons have well developed columnar structure with round or flat tops; the contact between A and B horizon is very distinct; and there is also an extremely leached, greyish horizon above the columnar B horizon. This platy A_2 horizon may vary in thickness from a mere film to two or three inches. Frequently the leached surface layer is eroded away exposing the hard clay of the B horizon in the bottom of shallow pits. These eroded pits have been given local names such as slick spots and blowouts. The physical behaviour of solodized solonetz

soils when wet or dry is also a very distinguishing feature. The top of the B horizon becomes sticky and impervious when wet and very hard when dry. These conditions, in general, are unsatisfactory for cultivation and plant growth and prompt the doubts in the minds of many people as to the suitability of such a soil for irrigation.

McGregor (33) investigated the solodized solonetz soils in the brown soil zone of south-eastern Alberta. He reported that these soils formed as a result of limited precipitation and a topography which tends to give incomplete drainage of relatively large areas. After studying the base exchange in these and adjacent normal soils he concluded that:

(1) The amount of exchangeable sodium in solodized areas was considerably lower than calcium or magnesium.

(2) A correlation existed between the degree of solonization and the amount of exchangeable sodium, a correlation also found by Westin (62) and Riecken and Stalwick (42).

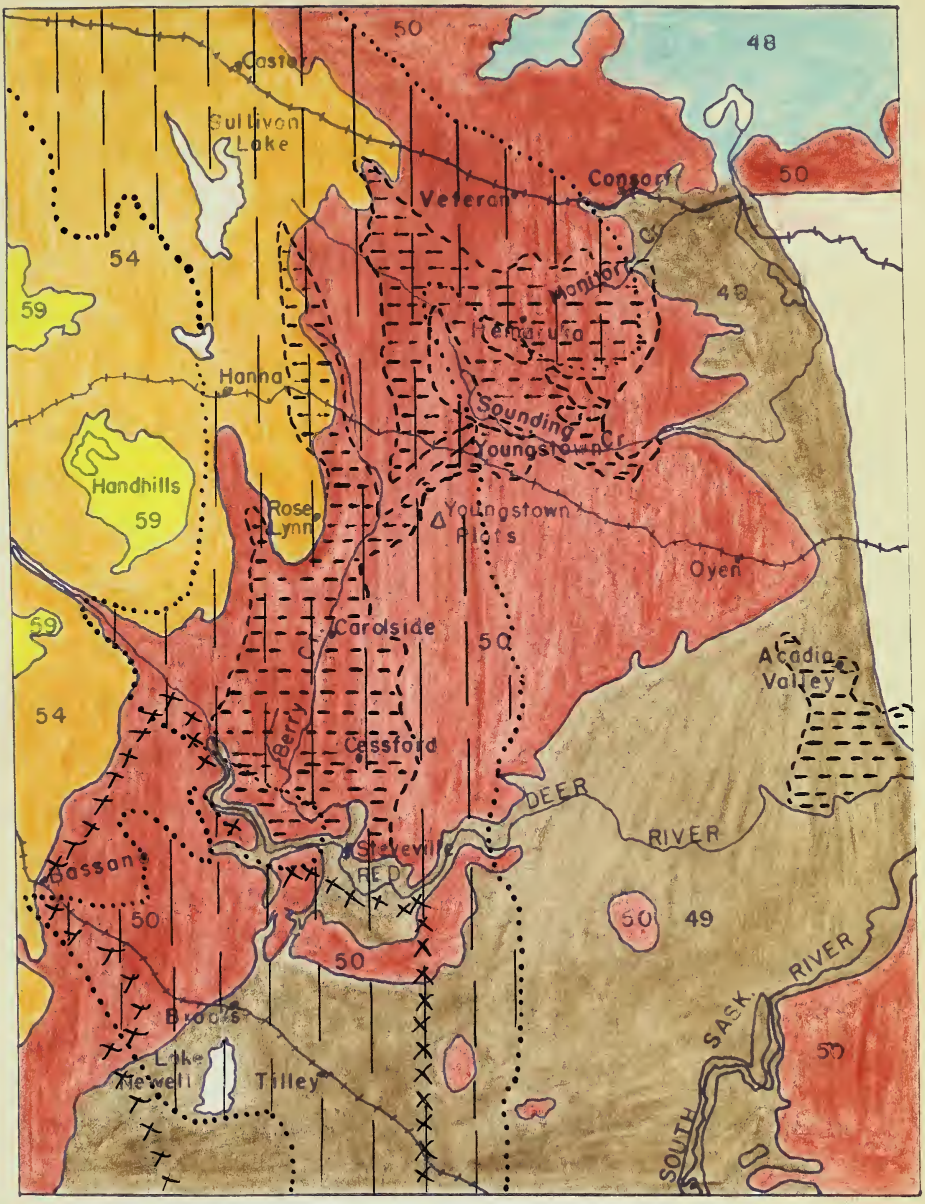
(3) A higher concentration of water soluble sodium was found in solonized profiles than in normal profiles.

Relationship Between Solodized Solonetz Areas and Underlying Geology in South Eastern Alberta.

The suggestion of a correlation between the occurrence of solodized solonetz soils and the underlying formation is not new. Kellogg (25) and Bentley (op. cit.) associated solonetz areas with parent material of shallow glacial till underlain by marine shales. The Bearpaw formation* underlies most of the solodized solonetz area in south eastern Alberta as outlined by Odynsky (see Plate I). Allan (1) and Wyatt and Newton (64) observed the abundant amount of calcium sulphate in the formation and also some sodium and magnesium sulphates. A report on subsurface water resources in the Sounding creek area by the Department of Lands and Mines of Alberta indicates that the predominant salts in water wells in the Bearpaw formation are mainly sodium chloride and sodium sulphate. Allan (2) points to imperfect drainage, shallow glacial till and sulphate salts as responsible for the alkali soils associated with the Bearpaw formation. From the facts presented, it would appear that there is a definite relationship between solodized solonetz soils and the Bearpaw formation in south eastern Alberta and it is worth noting that while almost the entire Red Deer project overlies Bearpaw bedrock much of the Eastern Irrigation District east of Brooks is over a different formation. Differences may therefore be expected in the adaptability of these two areas to irrigation practices.

* For description of geological formations in Alberta see Table 14 in Appendix.

GEOLOGICAL MAP OF RED DEER RIVER DIVERSION PROJECT



LEGEND

59	PASKAPOO FORMATION	49	OLDMAN FORMATION
54	EDMONTON FORMATION	48	VARIEGATED AND PALE BEDS
50	BEARPAW FORMATION		ODYNSKY'S SOLONETZ BELT
	RED DEER RIVER DIVERSION PROJECT		EASTERN IRRIGATION DISTRICT

Methods of Improving the Physical Characteristics of Saline and Alkali Soils

Richards (40) states that the improvement of saline and alkali soil involves practices and methods for the removal of excess salts and exchangeable sodium from the soil, and the improvement of the structure and tillage qualities of the soil. The removal of excess soluble salts is sometimes not sufficient to restore such soils to productivity. Weiser (61) says that according to Bradfield it is essential to restore the normal calcium-sodium ratio on the exchange complex in order to regain the normal physical condition of these soils.

The writer lists below the methods of Richards (op. cit.) and other writers (5, 7, 16, 21, 22, 23, 29, 30, 44, 49, 50 and 66) for improving the chemical and physical properties of saline and alkali soils:

A. Soil drainage by lowering the water table.
   (1) Deep open ditches
   (2) Tile lines
   (3) Pumping from wells

B. Improving the permeability of the soil profile.
   (1) Soil amendment treatments
   (2) Soil management practices

A large number of soil amendments have been tried and these may be listed as follows:

I. Chemical Amendments

(a) Inorganic chemicals

(1) Sulphur

(2) Sulphuric acid

(3) Gypsum

(4) Calcium carbonate

(5) Aluminium sulphate

(6) Calcium sulphate

(7) Fertilizers

(8) Calcium nitrate

(9) Ammonium sulphate

(10) Calcium oxide

(11) Calcium chloride

(12) Iron sulphate

(b) Organic chemicals

(1) Krilium

(2) Alconite

(3) Molasses

II. Physical Treatments

(a) Special tillage

(1) Deep ploughing

(2) Deep cultivation

(b) Miscellaneous

(1) Dynamite

(b) Miscellaneous

(2) Reclamation by use of deep rooted crops.

(3) Electrical treatment such as electrodialysis.

Likewise many management schemes have been tried out, the more important being:

(a) Crop rotation and management

(1) The use of salt tolerant crops

(2) The incorporation of legumes

(3) The application of fertilizers

(4) The application of manure

(b) Cultural practices

(1) Moisture content of soil maintained at optimum

(2) Use of special cultural implements.

(c) Irrigation practices

(1) Proper irrigation methods

(2) Correct water application

Soil drainage lowers the water table and also improves the permeability of the soil profile. Richards (op. cit.) stresses adequate drainage as the first essential in any reclamation program. A classical example of soil drainage is the reclamation of lakes in Holland as explained by Zuur (66). On the basis of experiments in California, Kelley (26) concludes that it is economically feasible to reclaim almost any

alkali soil provided it can be efficiently drained and an adequate supply of irrigation water is available.

The application of inorganic chemical amendments has been used by many investigators to improve the permeability and crop yield of saline and alkali soils. Hauser (22) and Russell (44) have reported that gypsum improved the permeability of certain soils. Bower (5) states that lime decreased while gypsum and sulphur increased infiltration rates, that sulphur tended to lower hay yields while gypsum and lime had no effect. The sulphur treatment gave the highest increase in the alfalfa stand and encouraged root growth downwards to a depth of forty inches in an experiment conducted by Fitts et al (14) using sulphur, gypsum and calcium chloride treatments at varying rates on slick spots. Shawarbi (49) mentions that aluminum sulphate, sulphuric acid and calcium sulphate reduced the alkalinity on Hungarian soils while calcium carbonate had no beneficial effects. In Kelley's experiments (26) a black alkali soil at Fresno was reclaimed by the use of gypsum, by sulphur, by iron sulphate or by alum. Russell (op. cit.) and Zuur (op. cit.) explain how land in Holland is reclaimed from the sea. Due to the large amounts of calcium carbonate in the sedimentary deposits the sodium soil is changed to a calcium soil on drainage and good soil structure is attained. Hubbell and Stubblefield (23) state that all the amendments in their experiment except calcium carbonate improved the percolation rate,

that sulfuric acid increased the total soluble salts, that none of the treatments, including gypsum, calcium nitrate and an activated sludge (alconite), had any effect on the formation of water stable aggregates.

Certain organic compounds have been successfully used to improve the physical structure of saline and problem soils. Shawarbi (op. cit.) mentions the successful reclamation of alkali soils by molasses treatment. A soil conditioner developed by Monsanto chemical company and given the trade name Krilium has improved the physical structure of certain problem soils. Sherwood (50) observed improved soil workability, reduced soil crusting and effective erosion control in his Krilium experiments. Improved crop yield and quality was also observed. Chepil (9) found that Krilium increased soil permeability, produced good soil tilth, and increased the proportion of water stable aggregates. Many studies and experiments are underway to find the most efficient method of using Krilium. Haise et al (21) showed that there was a significant decrease in yield with increasing rates of Krilium. Laws (30) noticed that the conditioner was more effective as an aggregating agent on sandy loam and clay loam than on heavy clay soils. He also noticed that the presence of calcium carbonate in the soil inhibited the effectiveness of the soil conditioner. Krilium shows spectacular ability to improve the physical structure of

soil. Its relation to plant growth and soil stabilization is not yet fully known.

The combination of physical and chemical amendments has great possibilities for improving the physical and chemical condition of saline and alkali soils. Russell (op. cit.) and Richards (op. cit.) report that the permeability of a soil can sometimes be increased by deep ploughing, particularly if gypsum is added or if gypsum is present in the soil. Smith (52) showed that subsoiling following placement of lime in a plow furrow improved the root system of clover. The combination of subsoil placement of lime and fertilizer improved sugar beet yield and infiltration rates in an experiment conducted by Martinez and Lugo-Lupez (35).

Novel methods have been used in the past for reclaiming alkali soils. Experiments have shown that dynamite will not improve the permeability of hard pan clay soils in Kansas (7). Shawarbi (op. cit.) says that electrodialysis of alkaline soils holds vast possibilities.

Soil management practices offer perhaps the most practical solution for the improvement of saline and alkali soil. A good crop rotation is essential. Smith (op. cit.) stresses a fertility program aimed at maintenance of organic matter. Lyon and Buckman (op. cit.) stress the importance of green manures and salt tolerant crops for alkali control.

Odynsky (op. cit.) advises the growing of soil improving crops such as alfalfa and sweet clover with occasional deep ploughing. Zuur (op. cit.) found that fertilizer application was essential on reclaimed land. Bower (op. cit.) concluded that nitrogen and phosphorus were essential in the fertilization program.

Moist alkali soils usually present a cultural problem. Richards (op. cit.) warns that alkali soils are subject to puddling and should not be cultivated when wet. Laws (29) and Smith (op. cit.) mention that the subsoil will shatter satisfactorily only if the moisture content of the soil is less than 16 per cent. Gardner (16) states that the permeability of sodium saturated soil was restored by freezing and thawing only when calcium chloride was added to replace the sodium ion. He comments on the advantages of a cold climate in restoring the structure and permeability in the process of reclaiming soils that have been injured by sodium salts.

The proper use of water and the quality of irrigation water is important in irrigated areas. Richards (op. cit.) explains the proper irrigation methods and correct water applications in order to maintain a favourable salt balance in the soil without excessive leaching of plant nutrients.

The quality of water may affect the physical condition of the soil and also plant growth. Richards lists three important factors in irrigation water: total salt content, the soluble sodium percentage and the boron content.

Experiments and methods mentioned indicate that the improvement and reclamation of saline and alkali soils is a complex problem. Shawarbi (op. cit.) refers to Stebutt's discussion of soil dynamics in the evolution of alkaline soil. Stebutt is reported to claim that the reclamation treatment must change the chemical, physical and biological processes that are continuously occurring in a soil in such a way that the evolution of the soil will lead to a normal agricultural soil.

In summarizing these opinions and findings it is obvious that a program for successful handling of solodized solonetz soils under irrigation should probably include improvement of soil drainage, the addition of soil amendments and proper soil management. Variations in program would result from varying local conditions.

Methods of Evaluating the Physical Structure of Soils

Baver (3) reports that there are direct and indirect methods for evaluating soil structure. The direct methods involve macroscopic and microscopic observations but these methods have not been sufficiently perfected as yet to provide

a complete picture of soil structure. The indirect methods of evaluating soil structure include aggregate analyses, porosity and permeability determinations and penetrometer evaluations.

Soil Aggregate Analysis

Aggregate analysis has been stimulated by the advent of soil conditioners since some method of evaluating their effects was needed. Baver (op. cit.) discusses various methods and states that an aggregate analysis aims to measure the percentage of water-stable secondary particles in the soil and the extent to which the finer mechanical separates are aggregated into coarser fractions. In general, Yoder's wet sieving technique (65) is the basis for most of the work done on this continent. The major problems in this type of analysis are:

(1) Pre-treatment of the sample

(2) Technique

(3) Expressing the results in a meaningful way.

Pre-treatment of the Sample -- Time of sampling has an effect on aggregation. Gish (17) reports that the season of the year and moisture content of the soil at the time of sampling have a marked influence on aggregation. The sample is usually air dried before analysis. Slater (51) noticed no effect on aggregation when the sample was air dried in the laboratory. Pre-treatment of the sample before sieving has been done in

several ways: wetting the sample by end over end shaking, spraying, wetting by capillary rise, rapid immersion, and by flooding in an evacuated flask. Nyhawan and Olmstead (36) found that treatment of samples before sieving greatly influenced the yield of aggregates larger than 0.2 mm. Van Bavel (60) in a recent publication criticizes vacuum wetting of the sample. He concluded that vacuum wetting of the sample introduced a large amount of random variation in the results of aggregate analysis and involved an extra amount of work. He does not recommend the use of vacuum wetting.

Technique -- Different wet sieving techniques used are suggested by Table 1. Van Bavel (op. cit.) recommends that the nature of the sieving apparatus is not important providing the specifications for the size of the sieves, frequency and strokes are met.

Expressing the Results in a Meaningful Way -- Schaller and Stockinger (46) indicate five ways for expressing aggregation data that have been in common use. These are: percentage aggregates greater than 2 mm., per cent greater than 1 mm., per cent greater than 0.25 mm., geometric mean, and mean weight diameter. They conclude that all methods are reliable, but greater accuracy is obtained by using geometric mean and mean weight diameter methods. Krumbein's (28) geometric mean and Van Bavel's (59) mean weight diameter both use a single value

TABLE 1

Variations in Sieve Sizes, Stroke, RPM, and Time of Sieving, used by Different Analysts for Aggregate Analysis

	Yoder (65)	Woodruff (63)	Elson (13)	Russell (45)	U. of A.
Sieve	5.0	6.7	8.0	5.0	4.0
sizes	2.0	4.0	5.0	2.0	2.0
in	1.0	2.0	2.0	1.0	1.0
mm.	0.5	1.0	1.0	0.5	0.5
	0.25	0.5	0.5	0.25	0.25
	0.10	0.25	0.25	0.10	0.125
		0.10	0.1		
Stroke	1 1/4"	4 7/8"	3 1/2"	1 1/2"	1 1/4"
R.P.M.	30	19	36	30	30
Time	30'	Varying	18'	30'	30'

to characterize the whole size distribution of the analysis. This has the advantage of rendering the data suitable for statistical analysis. Sherwood and Engebou (50), and Laws (30) have used wet sieving techniques to determine the effects of soil amendments on soil structure. Aggregation data are used to determine the effects of different soil treatments. Robinson and Page (43) state that reclamation of dispersed soil requires the use of soil amendments and organic matter Gish and Browning (17) noticed that soil and crop management practices had a marked effect on soil aggregation data. Hubbell and Stubblefield (23) determined the effects of soil amendments on soil aggregation by aggregate analysis.

Porosity Determinations

Baver (op. cit.) reports that most soil porosity measurements are based upon determinations of the apparent specific gravity. The capillary, and non capillary porosity may be calculated from the volume, weight, moisture content and density of the soil particles. Uhland and O'Neal (58) outline a method for porosity determination using undisturbed soil core samples and a tension plate.

Permeability Determinations

Soil permeability may be defined as the capacity of the soil to transmit water and air. Permeability can be measured quantitatively on undisturbed soil cores in terms of percolation.

Uhland and O'Neal outline a technique. Rates of percolation are usually expressed in inches per hour.

A wide variety of equipment and procedures have been used in the past for obtaining undisturbed soil cores. Lutz (31) Swanson (55) Uhland (op. cit.) Kelly et al (27) Goode and Christian (19) have developed equipment for taking undisturbed soil core samples. Soil cores are obtained by hammering or jacking the core sampler into the soil. Some core samplers have a rotary cutting head. The number of hammer blows required to obtain a soil core is sometimes used as a guide for evaluating soil permeability. Edminster et al (12) compared different soil core samplers with a view to standardization. This investigation led to the adoption of the Uhland core sampler as standard for experiments in the south-eastern states. Ukland's technique in general is the basis for soil permeability determinations and evaluations.

Data obtained from permeability determinations are useful in several respects. Fletcher and Livingstone (15) studied the physical character of an artificially eroded soil under legume for 10 years with that of an adjacent uneroded area. Their data indicate that for the upper several inches of soil the legume has significantly lowered volume weight, increased total porosity, increased rate of surface water intake and increased air flow. Uhland (57) investigated the physical properties of soils with undisturbed soil cores, as modified by crops and management. His data show that deep rooted legumes such as

kudzu and alfalfa increase the percolation rate for the entire soil profile.

Soil Penetrometer

A soil penetrometer consists mainly of a probe which is forced into the soil to measure soil consolidation.

Various types of penetrometers have been designed by soil scientists. The instruments have varied in design from simple hammer driven probes or impact penetrators (24,54 and 55) to devices with indicating or recording gauges (10,39,41 and 48).

Soil penetrometers have been used to locate compact profile layers, and determine soil hardness, measure soil moisture conditions and evaluate soil permeability. Culpin (10) noticed a close relationship between soil consolidation and the penetration of metal probes. Stone and Williams (54) measured soil hardness with their soil hardness gauge and suggested possible practical uses for the gauge. Reed (39) studied the effects of soil packing by tractors with a penetrometer. Shaw (48) concluded that soil moisture content in penetrometer evaluations was a greater factor in soil hardness than porosity. Jamison and Weaver (24) used penetrometer measurements to estimate soil prosity. Richards (40) felt that the usefulness of penetrometers had not been exploited enough in connection with profile studies. A particular advantage of a penetrometer, he says, is that it can be used under field conditions.

In connection with Shaw's conclusion, mentioned above, it is obvious that moisture content of soils must be taken into account in interpreting penetrometer data. Where, however, a large number of penetrometer readings are made in a small plot area where moisture conditions are uniform this factor is probably of only minor importance.

NATURE OF THE PRESENT STUDY

Attention has been called in the Introduction to the predominance of solodized solonetz soils in the proposed Red Deer irrigation project, and a brief description given of the problem at hand. Various methods of improving the physical condition of such soils were reviewed and also the results of such methods in different areas. The present study had as its object the testing of several soil amendments and the determination of their effects on the physical structure of the Hemaruka profile at the Youngstown plots when irrigation was applied, together with the effects of different cultural treatments.

It was decided that small scale experimental plots would economically determine the effects of soil amendments. A field experiment was set up in which treatments of krilium, sulphur, gypsum, manure and deep cultivation were applied on different plots. The variability of the soil and the effects of soil amendments in the field were determined by grain height measurements, yield data and penetrometer evaluations. Surface and profile soil samples from the experimental plots were studied in the laboratory and this study included aggregate analyses, mechanical analyses, permeability determinations, soluble salt content and nitrogen percentages.

METHODS USED

The Field Experiments

It was necessary that experimental plots be situated on solodized solonetz soils typical of the Red Deer irrigation project area. A source of water for irrigation was also essential. The combination of these two requirements was located fifteen miles south west of Youngstown, on an abandoned farmstead (SE 1/4 - 28 - 28 - 10 W of 4). There the soil profile is a Hemaruka loam and a stock watering dam provides the necessary irrigation water. The plots were staked on an area of typical "blow out" soil with soil characteristics and vegetation as illustrated in Plate II.

The plot design is also illustrated in Plate II. Blocks A, B and C are rotations arranged systematically in the four ranges. Seven treatments were chosen and these are randomized within each block. The rotations are as follows:

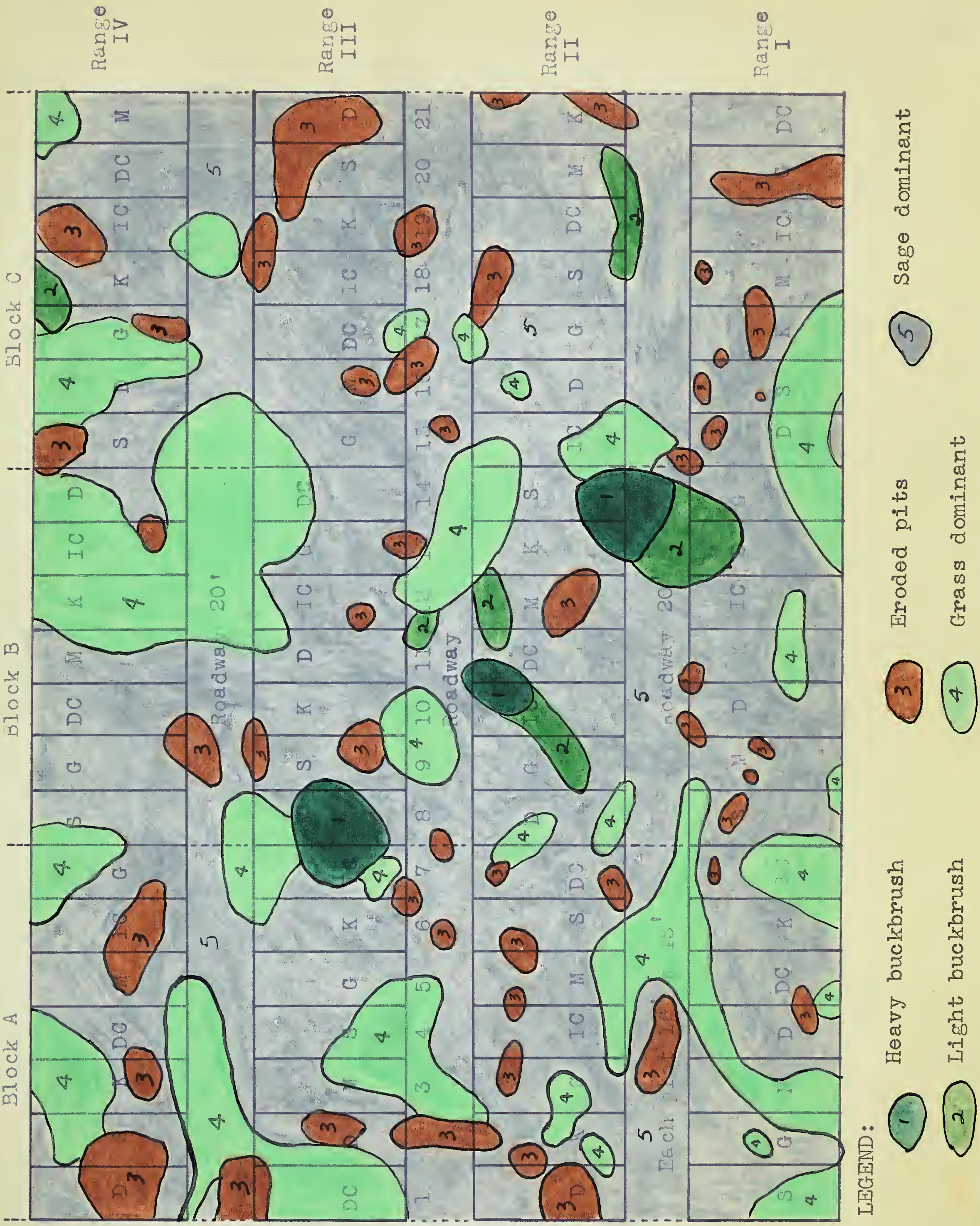
Block A .... sweet clover, grain

Block B .... continuous grain

Block C .... grain - sweet clover

PLATE II

YOUNGSTOWN PLOT VEGETATION PRIOR TO PLOWING 1952.



The 7 soil treatments selected were:

1952	Abbrev.
Krilium @ 1000 lbs. per acre on portion of plot	K_1
Krilium @ 2000 lbs. per acre on portion of plot	K_2
Manure @ 15 tons per acre	M
Sulphur @ 1000 lbs. per acre	S
Deep cultivation (depth 14")	DC
Irrigated check	IC
Dry check	D
1953	
Gypsum @ 1200 lbs. per acre	G
Krilium @ 2000 lbs. per acre on balance of plot	K
Manure @ 15 tons per acre	M
Sulphur (applied only in 1952)	S
Deep cultivation (depth 16")	DC
Irrigated check	IC
Dry check	D

The reactions which were theoretically expected to take place upon applying the various soil amendments are as follows:

(1) Krilium -- This synthetic polymer is a water soluble resin. In aqueous solutions it exists as a polyanion with many negative charges on the individual ions. The polyanions

presumably adsorb colloidal clay particles and the effect is the binding together of the clay particles by means of polymer bridges. This results in the formation of loose, spongy, clay aggregates. The treated soil mass becomes porous and friable and remarkably easy to work under certain conditions.

(2) Manure -- Dressings of farmyard manure can have very beneficial effects on soil structure. Manure increases the organic matter content of the soil, promotes biological activity and production of organic compounds that floculate clay particles, and can consequently improve soil structure.

(3) Sulphur -- Sulphur undergoes biological oxidation in moist soil which leads to the formation of sulphuric acid. If calcium carbonate is present in the soil the sulphuric acid converts it to calcium sulphate and calcium bicarbonate which then reacts with the sodium clay. If calcium carbonate is absent, the sodium is displaced from the soil by hydrogen. The material is then changed to some degree into a "hydrogen clay" which does not have the good physical and chemical properties of a calcium clay. An excessive application of sulphur can therefore make a soil far too acid for plant growth.

(4) Gypsum -- Exchangeable sodium on the clay complex can be replaced by calcium under field conditions by adding

a soluble calcium salt such as gypsum. The result is the replacement of sodium ions by calcium ions and the consequent augmentation of replaceable calcium.

(5) A hard pan soil can sometimes be broken up by sub-soiling. This action may promote root growth and may increase the water storage capacity of a soil. For these reasons it was felt desirable to include a deep cultivation treatment for comparison with the various amendments.

(6) For purposes of comparison both an irrigated and a dry check were included in the treatments.

<u>History of the Plots</u>

The experimental plots were laid out in May 1952 by the Research Council of Alberta and the Soils Department, University of Alberta. The Dominion Experimental Station, Lethbridge, commenced co-operative investigations on irrigation problems at this location. The writer was in charge of the University plots during the 1952 and the 1953 season. Much time was spent during the first summer doing pioneer work such as preparing the plot area, obtaining profile soil samples from each plot to a depth of four feet for future reference, building a fence to keep the range cattle out and accumulating equipment for cultural and irrigation pruposes. The plot area was ploughed and cultivated and the treatments were applied.

Campana barley was sown on the plots and sweet clover was broadcasted on block A. The rill method of irrigation was used but the soil surface was rather rough and did not lend itself for any type of surface irrigation. A dugout near the the plots was kept filled with water by a pump and sprinkler line from the dam. A small portable water pump forced water through a sprinkler line to the plot roadways, and by attaching nine garden hoses on the roadway line, it was possible to irrigate nine plots at one time. Approximately six inches of water were applied to each irrigated plot during the summer months of 1952. Due to unfavourable conditions of the soil surface and poor legume catch the plots were ploughed in the fall after harvesting and left in that condition during the winter months.

The purchase of a complete line of cultural equipment favoured the preparation of the plots in 1953. The plot area was re-ploughed, many plots were levelled and the treatments, including deep cultivation, were repeated with the exception of sulphur application. The krilium @ 1000 lbs. per acre treatment was replaced by the gypsum treatment. Thatcher wheat was sown on the plots and sweet clover was again broadcast on block A. Irrigation was done in the same manner as in 1952 but with a few modifications. The dugout was not used due to seepage loss and the water was obtained directly from the dam. The use of small tin troughs with controlled openings facili-

tated the control of water. These troughs were placed at the head of alternate plots and a garden hose was placed in each trough. Approximately eight inches of water were applied on each irrigated plot during the 1953 summer months. The deep cultivation treatment was done after harvesting. During the summer land level readings were obtained for each plot.

Field Studies

Yield Determinations -- The yield for a plot was obtained by cutting a square yard sample from each of three locations, designated a, b, and c, spaced equidistant down the centre of each plot. Each sample was dried, threshed and the yield of grain calculated on an acre basis.

Height Measurements -- The crop height was classified before harvesting in 1952 and 1953 and the boundaries of the various classes were recorded on the plot plan.

Penetrometer Studies -- The hard columnar B horizon of the Hemaruka is seen in Plate III. It is expected that eventually the effects of some treatments under irrigation will be a breakdown of the B horizon. A change in soil structure would only be obvious if future evaluations of the physical condition of the soil were compared with the soil structure prior to treatment application. It was thought that penetrometer readings would indicate such

PLATE III

THE HEMARUKA PROFILE

structural changes. The writer designed a self recording soil penetrometer in 1953 for the particular conditions at the Youngstown plots. This self recording soil penetrometer, as shown in Plate IV and Plate V has the following features:

1. The machine is light in weight and convenient to transport.
2. The graph carriage moves, relative to the ground surface at a constant rate which is controlled by the operator and this rate of movement can be replicated by any operator.
3. A self filling recording pen records the resistance to probe penetration in the soil. Movement of the pen in the "X" direction indicates the depth of probe penetration. The resistance encountered by the probe as it is forced into the soil is denoted by the movement of the pen in the "Y" direction. This results from and is proportional to the compression of two calibrated springs, and the compression of these springs is in turn proportional to penetration resistance.
4. After the recording pen on the carriage draws the resistance vs. depth line on the paper, the pen draws a "Y" axis when the graph carriage is pulled up, then as the probe is pulled from the ground, draws an "X" axis returning to its starting position,

PLATE IV

THE SELF RECORDING SOIL PENETROMETER

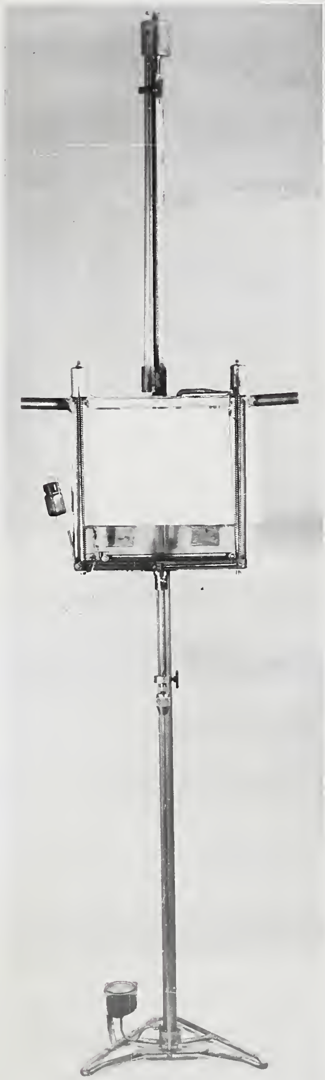


PLATE V

THE SELF RECORDING SOIL PENETROMETER

CLOSE UP OF GRAPH CARRIAGE

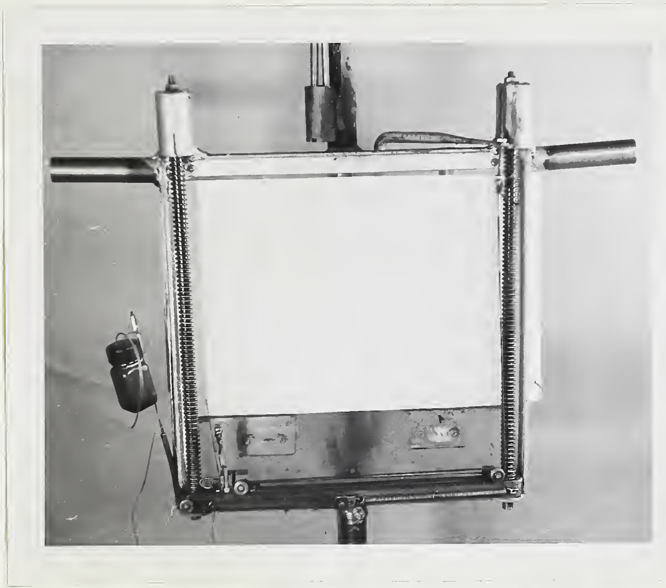
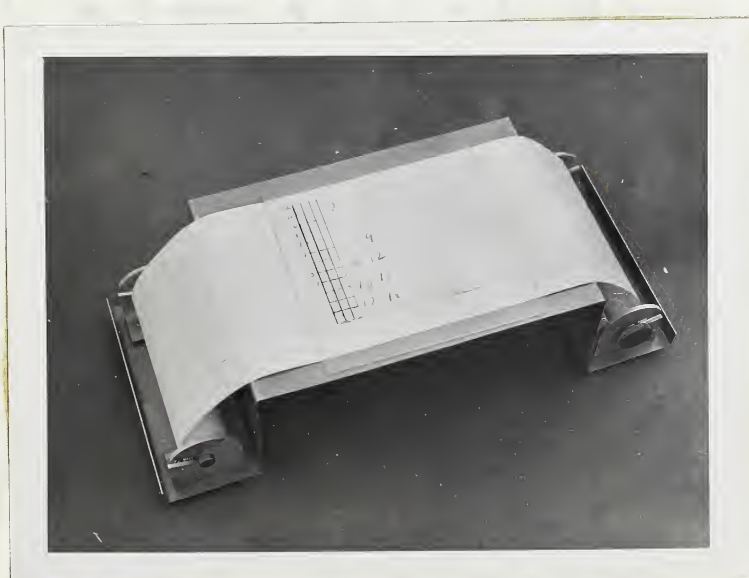


PLATE VI

THE MASTER GRAPH AND TABLE FOR PENETROMETER GRAPH ROLL



5. A blank paper roll is used instead of individual sheets and the number of consecutive graphs that can be drawn is limited only by the size of the roll. Paper rolls are simply and conveniently filed.
6. Replications are rapid and simple. No adjustments are necessary for replications as the pen returns to its starting position when the probe is lifted out of the soil. The probe is pushed into the soil, pulled out, moved to a new location and the process repeated. Where no extension to the probe is called for less than half a minute is required for each graph.
7. The penetrometer is designed to take readings to varying maximum depths of from eight inches to eight feet, the limit being determined only by soil consolidation.
8. Penetrometer readings can be taken in the field under windy conditions without affecting the efficiency of the machine or the operator.
9. Probes of different sizes and shapes can be attached to the probe stem to adapt probe resistance to spring tension.

Penetrometer readings of the Youngstown plots were first taken in June 1953. A minimum of three replications was taken at each of three locations, designated a, b, and c and coinciding with yield location, in each plot. The penetrometer settings were as follows:

probe diameter	-	5/16 inch
probe stem diameter	-	1/4 inch
spring tension	-	3 lbs./inch/spring
downward travel of graph carriage	-	1 ft./8 sec.

A stop collar was adjusted on the main stem so that the springs could be compressed only six inches. It took the writer two days to take penetrometer readings in the 84 plots, a minimum of 756 readings. These readings were repeated after harvesting, using the same technique.

A method of evaluating penetrometer graphs for practical application was necessary. Consequently the small table shown in Plate VI was constructed so that graph rolls could be conveniently examined. A master graph with graduated "X" and "Y" axes corresponding to the resistance and depth of probe penetration was drawn on a lucite sheet. To evaluate the graphs, the master graph was placed on the field graph, superimposing X and Y axes, and the desired information obtained from a study of the average curve, which was determined by visual estimation.

Information obtained from penetrometer graphs include the resistance of the first, second and third inch of surface soil to probe penetration, and the depth of isoprobes. Surface soil resistance was determined by allocating resistance units to the "Y" axis and then evaluating the resistance in each case. The term "isoprobes" designates points in the profile with equal resistance. The depth of isoprobes was determined from the graphs as the depths at which the resistance of probe penetration compressed the springs six inches. These isoprobes were plotted on graphs showing the profile of the plots. A profile graph was made of the plots in which the surface soil was plotted to scale from level readings and isoprobes were plotted to the depth below surface. This profile study was made for locations a, b and c of each range, and included isoprobes from June and September readings (1953). A three dimensional plan of the Youngstown plots was also made to scale using level readings and June 1953 isoprobes.

Laboratory Studies

Soil samples used for laboratory studies were obtained in the following manner:

1. Undisturbed soil core samples, using the Uhland core sampler and Uhland's technique, were obtained

from the plots after harvesting in 1952. Permeability and porosity determinations were made from these samples.

2. Profile soil samples of certain plots were taken in June, 1953, at six inch intervals to a depth of four feet with a King tube. The soluble salt content and mechanical analysis of these samples were determined.

3. A composite soil sample from each plot was taken at an average depth of three inches after harvesting in 1953. Laboratory study of each plot sample included aggregate analysis and mechanical analysis. Nitrogen percentages were determined on a few of the soils darkest in color and a few of the lightest in color to determine the extremes of N content.

Aggregate Analysis

Yoder's technique (65) for aggregate analysis was followed except for modification in the pre-treatment of the sample. The composite soil sample was air dried, then passed through a 1/2" mesh sieve. Larger clods were crushed by a heavy roller on tracks 1/4" high thus eliminating unnecessary disruption of aggregation and were re-sieved through the 1/2" mesh sieve. A 50 gram sample was used and wetting of the

sample was done under vacuum. The apparatus for vacuum wetting of the sample is shown on Plate VII and the wet-sieving equipment is shown on Plate VIII. Specifications regarding sieve size and machine operation are shown in Table I in comparison with figures used by other workers.

Mechanical Analysis

The revised procedure of the pipette method as suggested by Toogood and Peters (56) was used for mechanical analysis of soil samples.

Permeability and Porosity Studies

Permeability and porosity studies were conducted according to procedures used by Uhland and O'Neal (58).

Soluble Salts

Conductivity measurements are expressed in millimhos/cm^2 on a soil to water ratio of 1:5, using a standardized conductivity cell in conjunction with a Wheatstone Bridge. Standard methods currently used by the Soils Department, University of Alberta, were used to determine the soluble salts on the 1:5 extract.

PLATE VII

APPARATUS FOR VACUUM WETTING OF THE SAMPLE

FOR AGGREGATE ANALYSIS

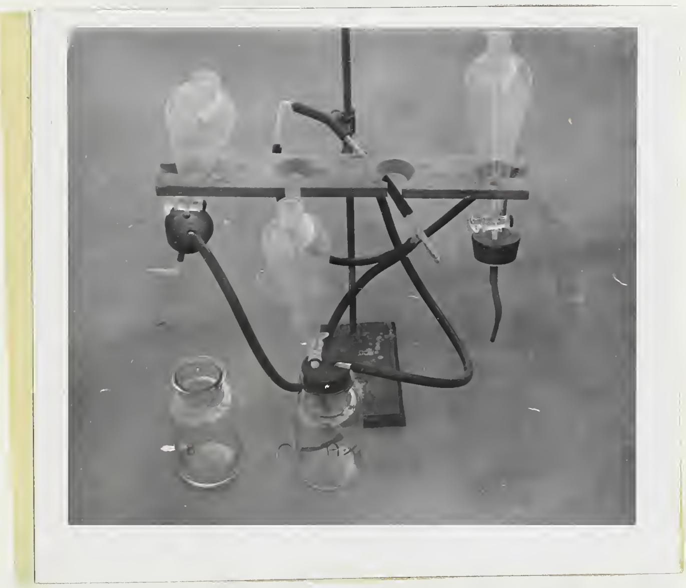
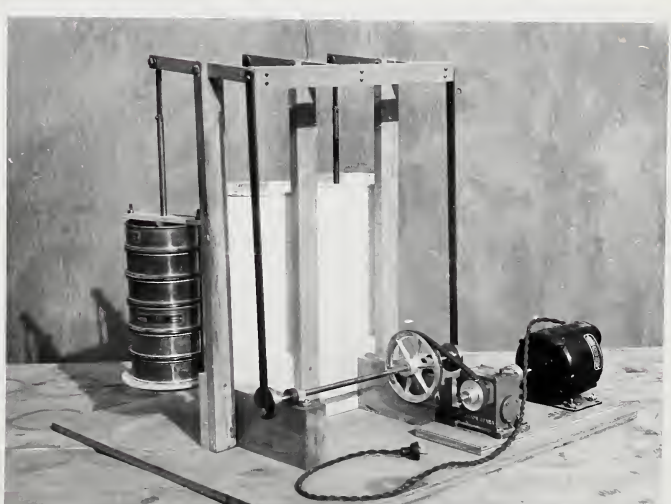


PLATE VIII

WET SIEVING EQUIPMENT USED FOR AGGREGATE ANALYSES

Front view

Rear view



The techniques used for salt determinations were:

Na	by flame photometer.
Ca and Mg.	Ca was determined by titrations with .01 versene using murexide as indicator Ca plus Mg was determined by titrations with .01 versene using erichrome black T indicator. Mg was determined by difference.
SO_4	by turbidimetric method following mimeograph method by Schroer and Bentley as used in the Soils lab.
HCO_3	by titrations with .02M H_2SO_4 using methyl orange indicator.
CO_3	by titrations with .02N H_2SO_4 using phenolphthalein indicator.
Cl	by titrations with $AgNO_3$ using potassium chromate indicator.

Nitrogen Determination

Nitrogen was determined by the modified Kjeldahl method using selenium as described by the association of official agricultural chemists.

RESULTS

Field Results

The height measurements made on barley, 1952, and wheat, 1953, are diagrammatically illustrated in Plate IX and Plate X. Note the extreme variability which in both years largely masked the effects of treatments. Note too the better growth in 1953.

The average yield of grain for each treatment is graphically presented in Plate XI. Table 2 and 3 give the data in full for the two years as well as the analysis of variance of the wheat and barley yields, the average yields and the L.S.D. Statistical analysis showed no significant differences due to treatments in 1952 while in 1953 some differences were obtained. Table 4 lists the wheat yield in grams for each square yard sample in a representative portion of the plots and the data show the large amount of variation not only between plots but also within the plots. With such variations it is not surprising that few significant differences were revealed by statistical analysis. Such variation is also indicative of the extremely variable nature of the soil.

The depth of penetrometer isoprobes for June and September, 1953 in each plot is illustrated in the profile

diagrams of Plate XVI, XVII, XVIII and XIX in the Appendix. Note that, in general, the June isoprobes were much deeper than the September isoprobes. This may be accounted for by the fact that heavy rains lead to a high soil moisture content in June. By September the soil had dried out and the isoprobes were closer to the surface. In a few cases the September isoprobes were deeper than the June indicating a softening of soil structure permitting deeper probe penetration. The large variability in the soil from plot to plot is again evident from a study of the profile diagrams.

The data for isoprobe measurements are summarized in Table 5, each figure representing an average of 108 measurements. The June and September isoprobe data are given in full in Table 6 and 7 as well as the analysis of variance and treatment averages. The June data show no significant differences on statistical analysis, but show a greater average depth of isoprobes than the September readings. The September data (see Table 5) show krilium, gypsum, and sulphur as having caused a significant difference over the remaining treatments. These treatments apparently lowered the isoprobes, indicating a beneficial effect on the soil.

A three dimensional model of the plots showing relief and June isoprobes was photographed and is shown in Plate XII. This model was of value in studying effects of

native vegetation, topography and profile and in relating these to crop responses.

The hardness of the surface soil shown by the resistance as measured by penetrometer probe penetration of the first, second, and third inch for each treatment is graphically presented in Plate XIII. Also shown is in the mean weight diameter of soil aggregates for each treatment. The resistance factor represents the average of a minimum of 108 penetrometer readings while the mean weight diameter represents the average of 12 replicates. The data and the analysis of variance for the resistance factor and aggregate analysis are given in Table 8, 9, 10 and 11. They show krilium as the only effective treatment for soil aggregation as measured by aggregate analysis, while krilium, gypsum and sulphur were found to cause significant effects when measured by the resistance factor.

Laboratory Results

The results of mechanical analysis of surface soil from each of the 84 plots are pinpointed on the soil textural triangle in Plate XIV. Note the variability in texture in this two acre area.

Aggregate analysis studies done in the laboratory have already been referred to in connection with resistance

factor measurements.

Permeability rates and porosity as measured by the Uhland soil core technique and mechanical analysis are used in Plate XV to illustrate the wide differences in physical characteristics between a selected eroded pit profile in Range III and a permeable profile in Range IV. Note the different permeability rates in the two profiles and also the variations in the mechanical analysis of the eroded pit profile.

The variations in soluble salts of several profile samples is indicated in Table 12. In general the sodium content is higher than the calcium or magnesium in the soil profiles while calcium tends to increase with increasing depth. The approximate limits of salinity according to the conductivity scale on a 1:5 soil to water ratio used by Alberta Soil Survey are as follows:

Conductivity	Soluble salts-percentage	Effects
0 - .4	0 - .15	No evidence of salt injury.
.4 - .8	.15 - .35	Sensitive crops do not thrive. Tolerant crops may do well.
.8 - 1.5	.35 - .65	Crop growth restricted. Fields usually poor.
1.5 -	Above .65	Only a few species survive.

In general, Table 12 shows a low conductivity for the surface six inches of soil, but conductivity increases rapidly with increasing depth in most cases and reaches a salinity which might be toxic to plants.

Variations in soil fertility between plots is estimated by determining the nitrogen content of several surface soil samples (see Table 13). The data indicate the low level of organic matter present, characteristic of the brown soil zone.

PLATE IX

HEIGHT MEASUREMENTS OF BARLEY AT YOUNGSTOWN PLOTS

September, 1952.

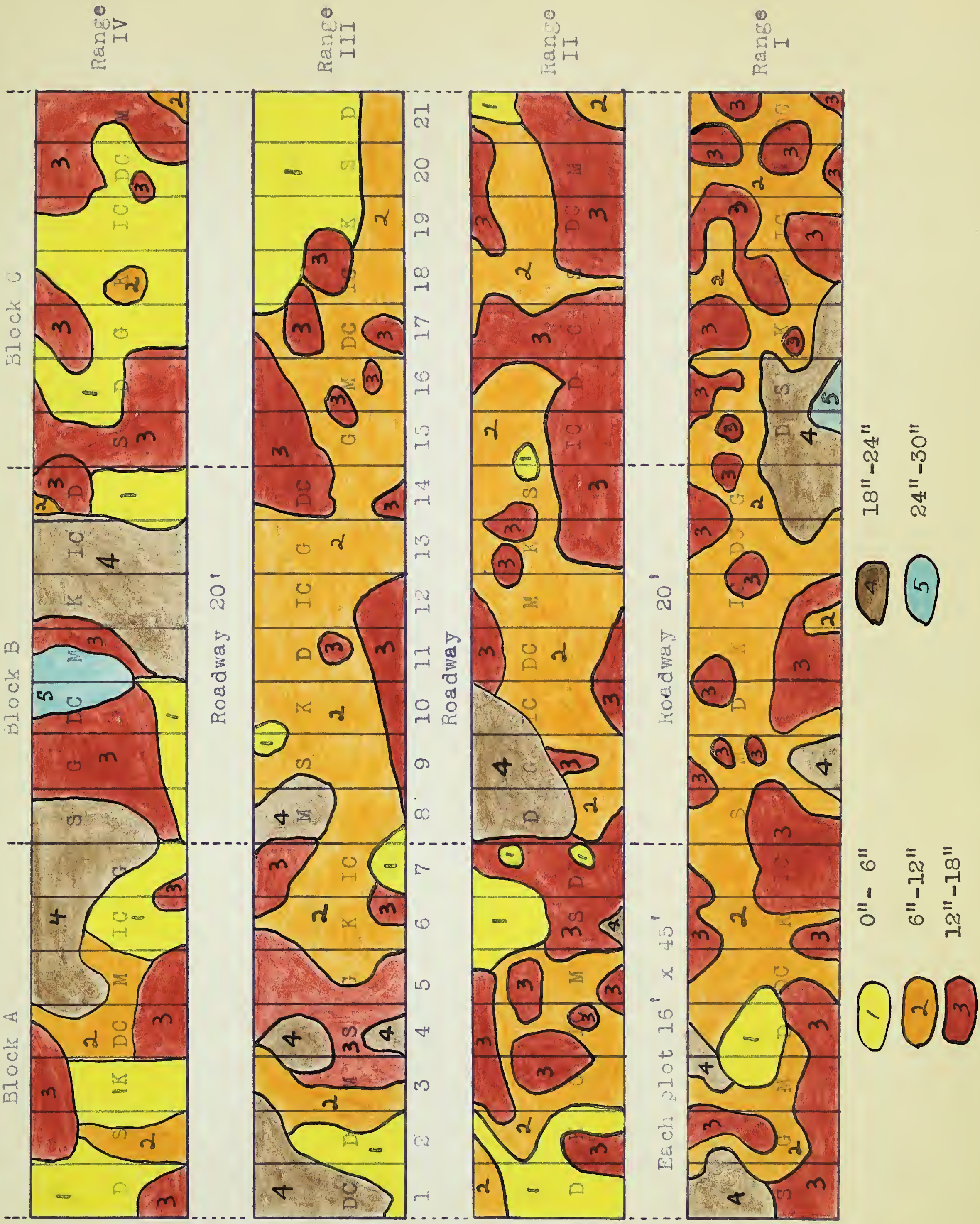


PLATE X

HEIGHT MEASUREMENTS OF WHEAT AT YOUNGSTOWN PLOTS

September, 1953.

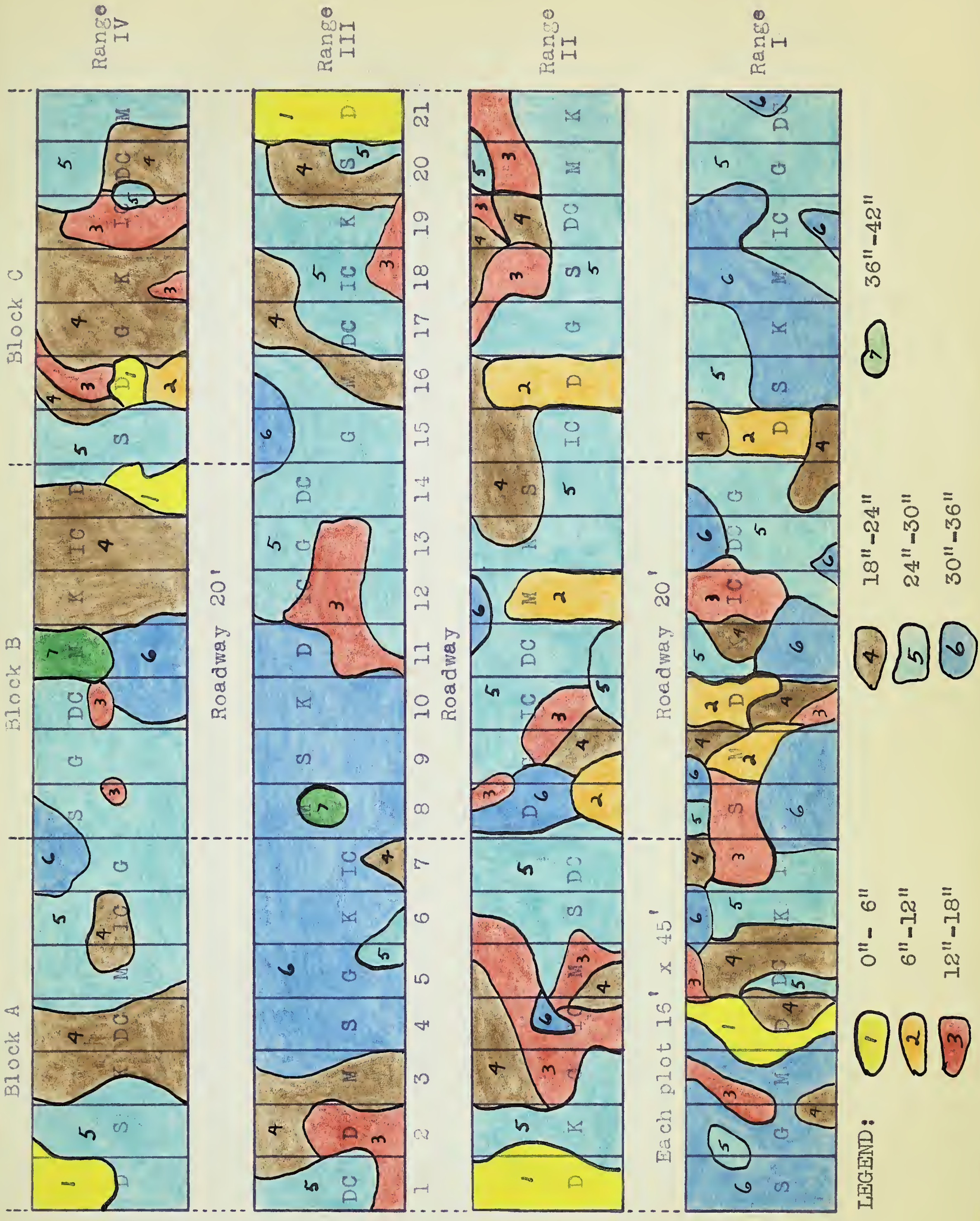
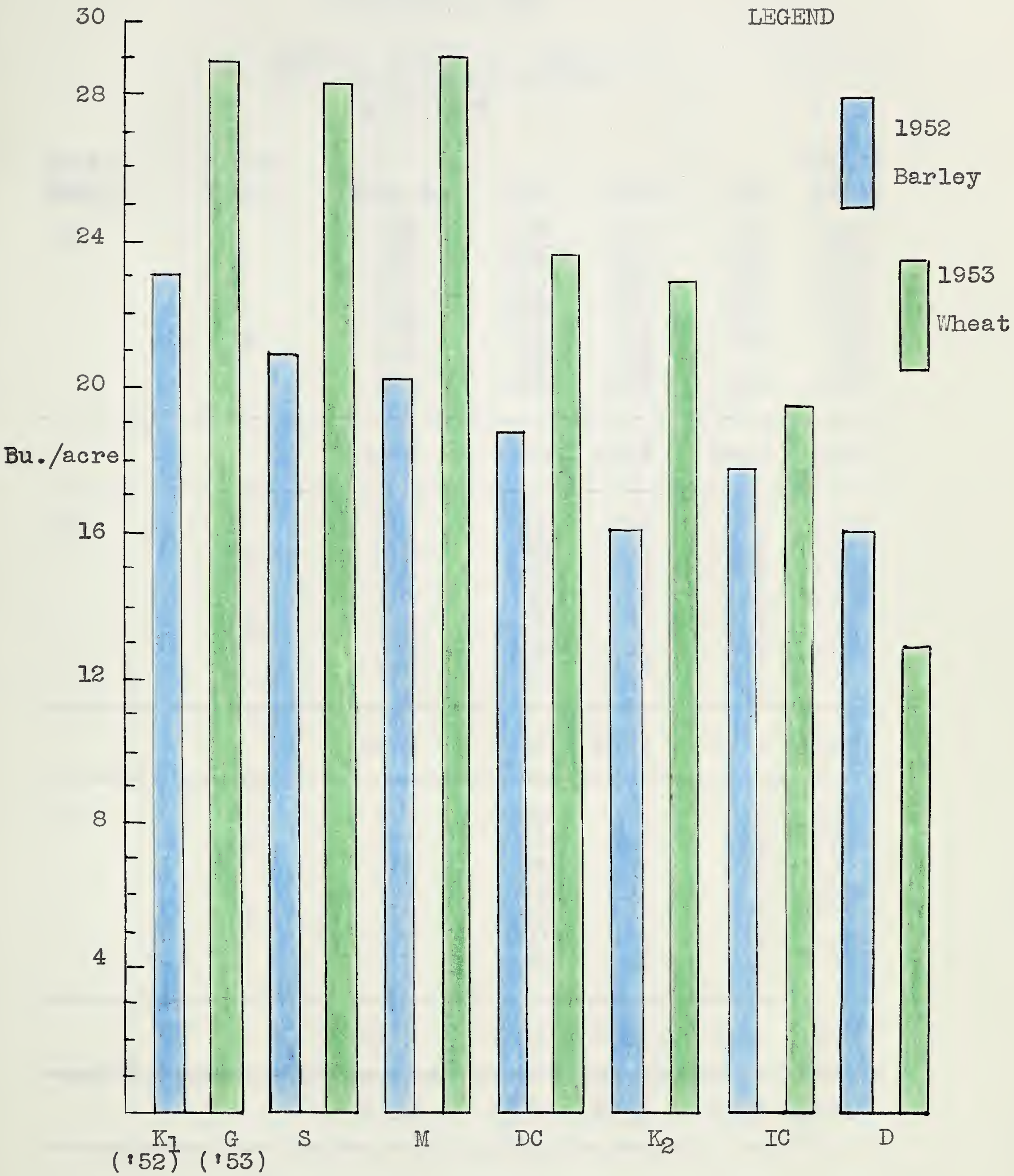


PLATE XI

YOUNGSTOWN PLOT YIELDS



TREATMENTS

TABLE 2

YOUNGSTOWN PLOTS

BARLEY YIELD - 1952
AND ANALYSIS OF VARIANCE
(gms./plot)

Rotation	Treatment	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	S	596	297	695	262	1850
	K	304	254	476	492	1526
	DC	223	317	668	129	1337
	M	339	284	306	290	1219
	K_2	208	437	42	180	867
	D	111	24	233	1	369
	IC	205	582	298	275	1360
		1986	2195	2718	1629	8528
B	S	317	236	285	662	1500
	K_1	316	708	285	327	1636
	DC	384	302	464	526	1676
	M	145	102	689	854	1790
	K_2	487	176	254	474	1391
	D	382	610	685	242	1919
	IC	458	264	278	570	1570
		2489	2398	2940	3655	11482
C	S	604	305	4	237	1150
	K_1	175	711	528	359	1773
	DC	310	354	154	226	1044
	M	484	329	191	432	1436
	K_2	394	530	161	134	1219
	D	308	493	2	383	1186
	IC	578	220	92	10	900
		2853	2942	1132	1781	8708
		7328	7535	6790	7065	28718

TABLE 2 (cont'd.)

ANALYSIS OF VARIANCE OF BARLEY YIELDS

Treatments	(grams)	Average		bu./acre
S	4500	S	375	22.3
K_1	4935	K_1	411	24.4
DC	4057	DC	338	24.1
M	4445	M	370	21.9
K_2	3477	K_2	290	17.2
D	3474	D	290	17.2
IC	3830	IC	319	18.9
	28718			

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	14,917	3	4972	.055		
Rotation	195,876	2	97938	1.08		
Error (1)	542,483	6	90413			
Trts.	152,580	6	25430	.76	2.29	3.18
Rot.x TRTs.	359,579	12	29965	.90		
Error (2)	1,794,386	54				
T O T A L	3,059,821	83				

No LSD.

TABLE 3

YOUNGSTOWN PLOTS

WHEAT YIELD - 1953
AND ANALYSIS OF VARIANCE
(gms/plot)

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	S	503	314	662	477	1956
	K	419	290	444	282	1435
	G	456	347	467	562	1832
	M	563	197	423	446	1629
	DC	284	287	335	308	1214
	IC	387	310	415	476	1588
	D	120	14	126	192	452
		2732	1759	2872	2743	10106
B	S	461	331	513	622	1927
	K	524	464	484	93	1565
	G	465	558	436	503	1962
	M	256	227	851	807	2141
	DC	516	351	569	470	1906
	IC	176	288	283	106	853
	D	259	421	496	294	1470
		2657	2640	3632	2895	11824
C	S	484	352	355	615	1806
	K	483	365	447	332	1627
	G	472	623	567	471	2133
	M	523	355	548	638	2064
	DC	461	467	257	459	1644
	IC	513	477	327	157	1474
	D	165	194	1	289	649
		3101	2833	2502	2961	11397
		8490	7232	9006	8599	33327

TABLE 3 (cont'd.)

ANALYSIS OF VARIANCE OF WHEAT YIELDS

Treatments		Average	(grams)	bu./acre
S	5689	S	474	28.1
K	4627	K	385	22.8
G	5927	G	494	29.3
M	5834	M	486	28.8
DC	4764	DC	397	23.6
IC	3915	IC	326	19.3
D	2571	D	214	12.7
	33327			

Source of Variation	SS	DF	MS	F
Reps.	83834	3	27945	1.11
Rotations	57149	2	28574	1.14
Error (1)	151051	6	25175	
Trts.	741821	6	123637	7.83**
Rot. x Trts.	285357	12	23779	1.51
Error (2)	852387	54	15785	
T O T A L	2171599	83		

LSD at 5% level of significance = 102.6 g. = 6.1 bu./ac.

LSD at 1% level of significance = 115.5 g. = 6.9 bu./ac.

TABLE 4

WHEAT YIELDS IN GRAMS OF EACH SQUARE YARD SAMPLE

IN PART OF THE YOUNGSTOWN PLOTS, 1953.

	Range I.					Range II.				
Plot	Tre-at-ment	a.	b.	c.	Total	Tre-at-ment	a.	b.	c.	Total
1	S	120	178	205	503	D	0	0	14	14
2	G	156	174	126	456	K	50	138	102	290
3	M	151	269	143	563	G	146	69	132	347
4	D	99	0	21	120	IC	56	150	104	310
5	DC	149	62	73	284	M	92	80	25	197
6	K	148	107	164	419	S	143	130	41	314
7	IC	144	187	56	387	DC	107	93	87	287

	Range III.					Range IV.				
15	G	187	204	176	567	S	268	212	135	615
16	M	200	168	180	548	D	9	104	176	289
17	DC	80	106	71	257	G	208	107	156	471
18	IC	121	110	96	327	K	118	130	84	332
19	K	172	110	165	447	IC	25	68	64	157
20	S	153	92	110	355	DC	119	136	204	459
21	D	0	0	1	1	M	203	185	250	638

TABLE 5

YOUNGSTOWN PLOTS

THE AVERAGE DEPTH OF ISOPROBES

1953

Treatment	Depth (inches)	
	June	September
Krilium	20.2	10.7
Gypsum	19.5	12.8
Sulphur	21.7	10.0
Manure	19.8	5.8
Deep Cultivation	21.1	5.6
Irrigated Check	16.0	6.8
Dry Check	19.2	7.8

TABLE 6

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

DEPTH OF ISOPROBES (INCHES)

June 1953.

AND ANALYSIS OF VARIANCE

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	K	8	15	30	27	80
	G	18	17	14	28	77
	S	33	19	25	32	109
	M	25	15	11	18	69
	DC	19	29	51	19	118
	IC	9	19	12	17	57
	D	16	10	18	20	64
		128	124	161	161	574
B	K	9	12	33	42	96
	G	13	19	13	9	54
	S	19	26	28	21	94
	M	18	21	30	42	111
	DC	15	19	17	24	75
	IC	10	9	18	33	70
	D	23	38	27	15	103
		107	144	166	186	603
C	K	28	20	9	9	66
	G	26	23	21	33	103
	S	12	12	18	16	58
	M	13	10	11	23	57
	DC	14	14	22	11	61
	IC	25	19	12	13	69
	D	15	31	7	13	66
		133	129	100	118	480
		368	397	427	465	1657

TABLE 6 (cont'd.)

ANALYSIS OF VARIANCE FOR JUNE ISOPROBES

Treatment		Average	
K	242	K	20.1
G	234	G	19.5
S	261	S	21.7
M	237	M	19.8
DC	254	DC	21.1
IC	196	IC	16.3
D	233	D	19.4
	1657		

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	247	3	82.3	.47		
Rotation	296	2	148	.84		
Error (1)	1056	6	176			
Trts.	217	6	36.2	.64	2.29	3.18
Rot. x Trt.	1570	12	13.1	.23		
Error (2)	3041	54	56.3			
	6427	83				

Treatments not significant - No LSD.

TABLE 7

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

DEPTH OF ISOPROBES (INCHES)
AND ANALYSIS OF VARIANCE
September 1953.

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	K	9	3	9	7	28
	G	8	9	14	12	43
	S	9	4	17	14	44
	M	2	1	6	2	11
	DC	1	2	5	3	11
	IC	6	3	5	6	20
	D	5	1	1	9	26
		40	23	67	53	183
B	K	14	15	12	19	60
	G	11	8	10	12	41
	S	12	8	13	15	48
	M	4	3	10	4	21
	DC	7	7	10	9	33
	IC	8	7	3	18	36
	D	8	14	11	7	40
		64	62	69	84	279
C	K	16	8	6	12	42
	G	13	15	12	22	62
	S	15	7	5	11	38
	M	12	9	5	11	37
	DC	4	4	3	8	19
	IC	17	4	3	2	26
	D	11	6	2	9	28
		88	53	36	75	252
		192	138	172	212	714

TABLE 7 (cont'd.)

ANALYSIS OF VARIANCE FOR SEPTEMBER ISOPROBES

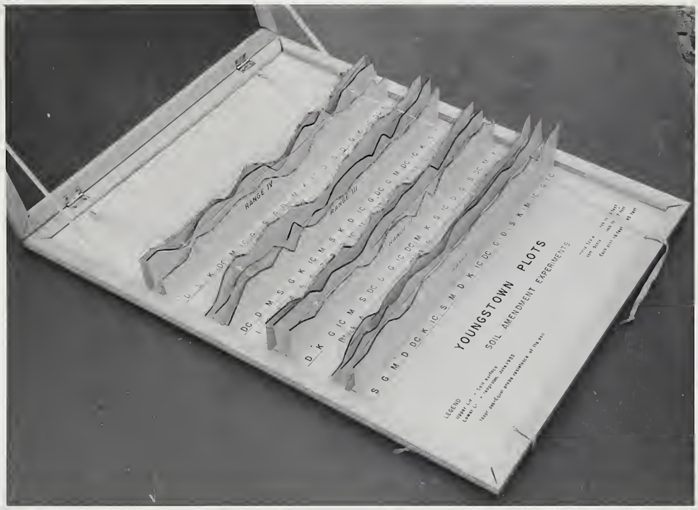
Treatment		Average	
K	130	K	10.7
G	146	G	12.8
S	130	S	10.0
M	69	M	5.8
DC	63	DC	5.6
IC	82	IC	6.8
D	94	D	7.8
	714		

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	142	3	47.3	1.02		
Rotation	175	2	87.5	1.88		
Error (1)	279	6	46.5			
Trts.	548	6	91.3	10.26**	2.29	3.18
Rot. x Trts.	243	12	20.3	2.28		
Error (2)	480	54	8.9			
TOTAL	1867	83				

LSD at 5% level of significance = 2.44
LSD at 1% level of significance = 3.29

PLATE XII

A THREE DIMENSIONAL MODEL OF THE YOUNGSTOWN PLOTS SHOWING PLOT RELIEF AND POSITION OF JUNE (1953) ISOPROBES



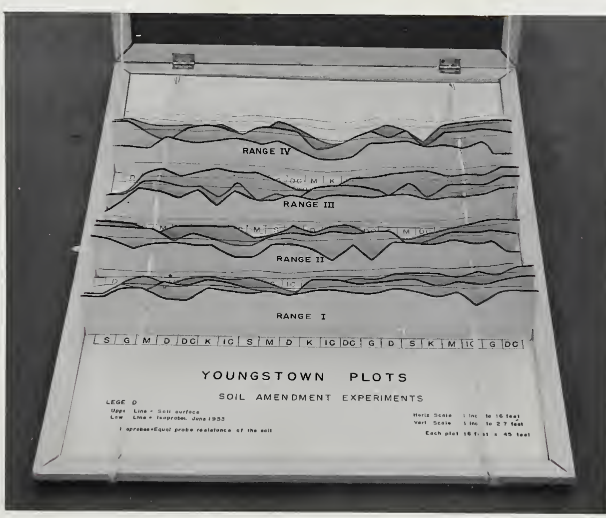
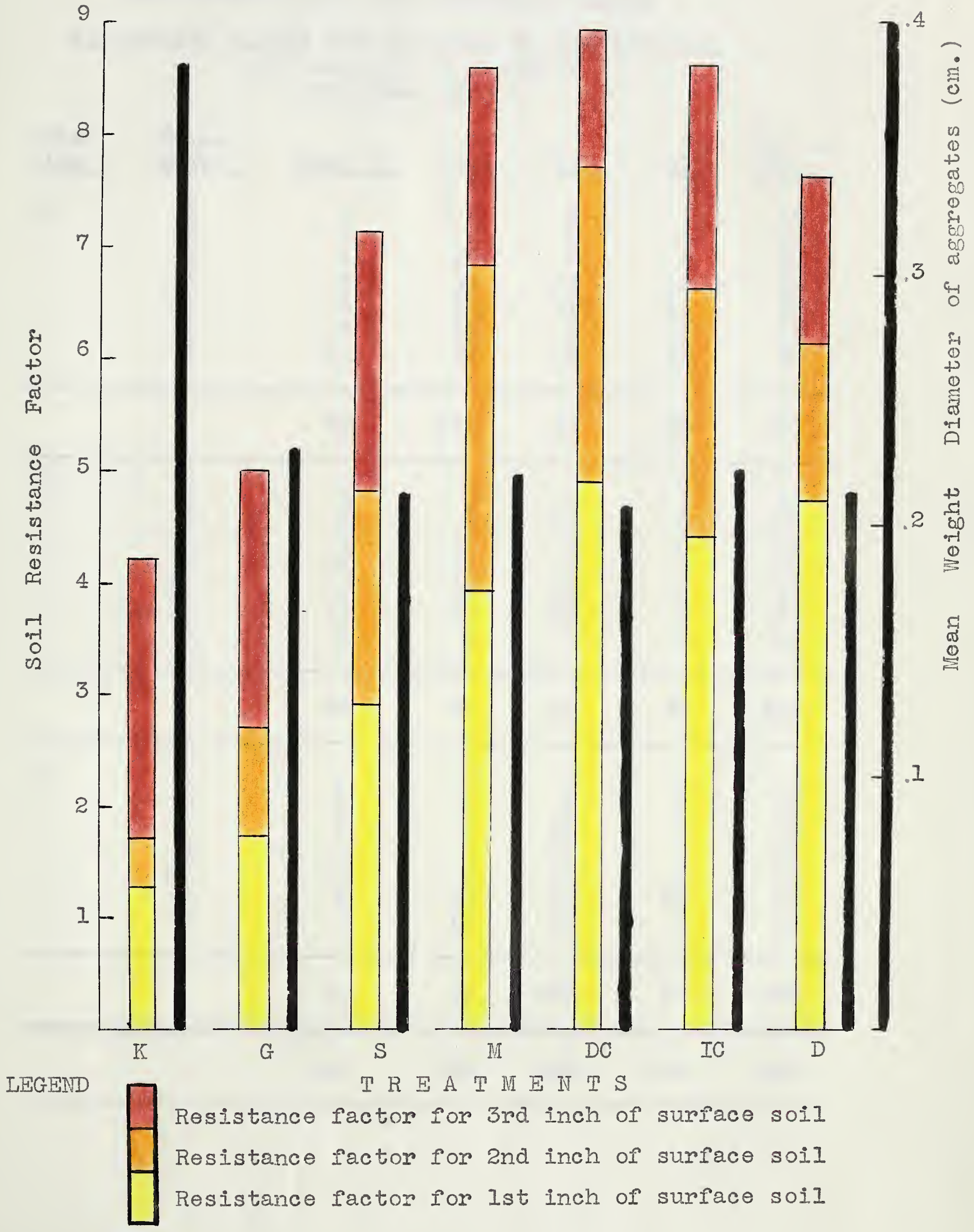


PLATE XIII

YOUNGSTOWN PLOTS

HARDNESS AND AGGREGATE ANALYSIS OF SURFACE SOIL



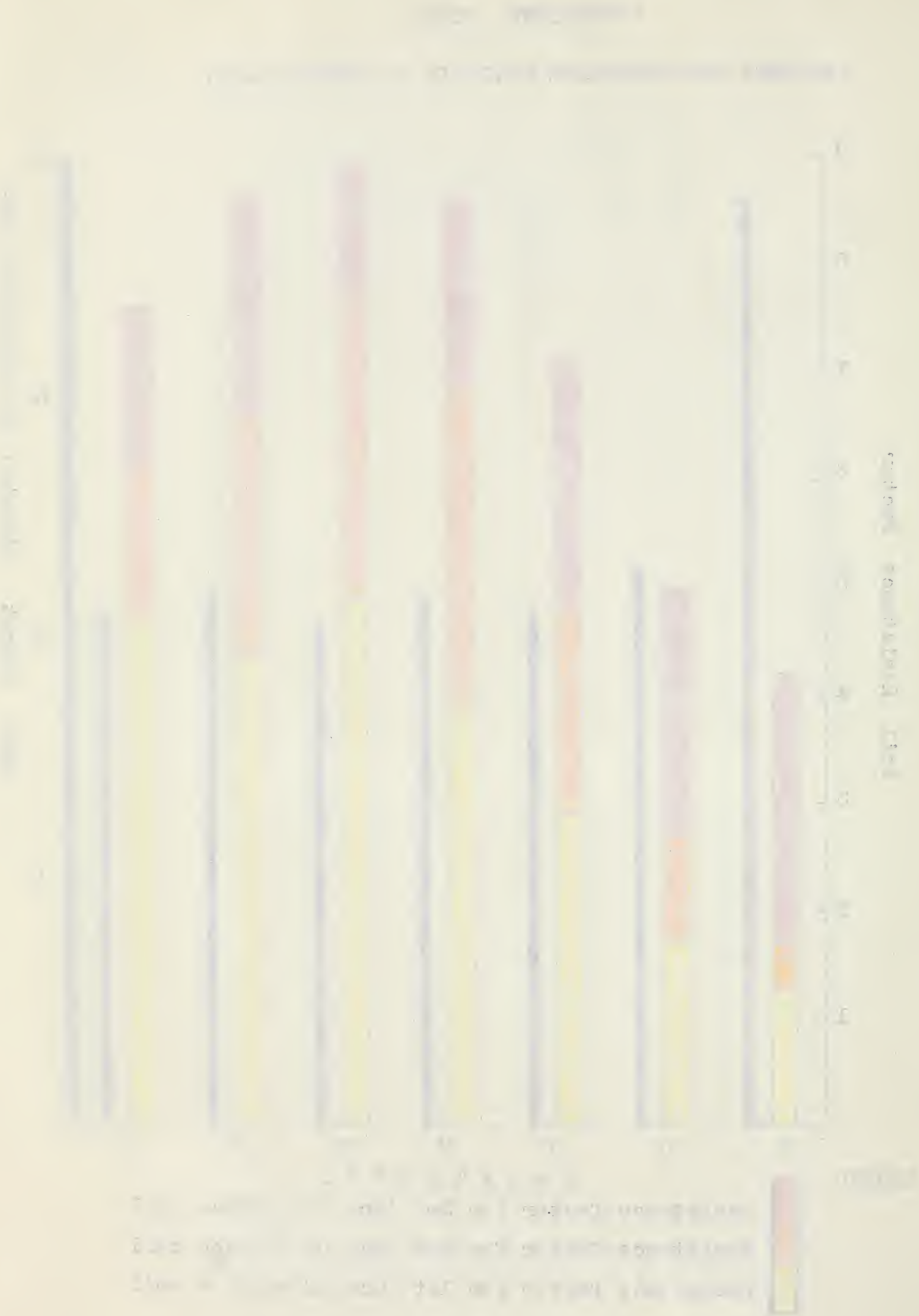


TABLE 8

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

RESISTANCE FACTOR FOR 1ST INCH OF SURFACE SOIL
AND ANALYSIS OF VARIANCE
September 1953

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	K	3	1	5	7	16
	G	3	6	2	3	14
	S	4	27	4	8	43
	M	7	31	15	10	63
	DC	36	25	11	11	83
	IC	8	16	6	10	40
	D	25	32	16	19	92
		86	138	59	68	351
B	K	3	3	5	3	14
	G	9	9	11	5	34
	S	5	10	5	6	26
	M	24	21	4	5	54
	DC	8	19	15	5	47
	IC	13	13	10	6	42
	D	6	9	3	4	22
		68	84	53	34	239
C	K	2	8	3	2	15
	G	4	1	6	2	13
	S	6	3	25	3	37
	M	5	5	14	1	25
	DC	13	6	21	5	45
	IC	6	19	25	26	76
	D	3	15	32	5	55
		39	57	126	44	266
		193	279	238	146	856

TABLE 8 (cont'd.)

ANALYSIS OF VARIANCE FOR RESISTANCE FACTOR FOR 1ST INCH OF SURFACE SOIL

Treatment		Average	
K	45	K	3.8
G	61	G	5.1
S	106	S	8.8
M	142	M	11.8
DC	175	DC	14.6
IC	158	IC	13.2
D	169	D	14.1
	856		

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	469	3	156.3	.98		
Rotations	244	2	122	.76		
Error (1)	960	6	160			
Trts.	1385	6	230.8	6.52**		
Rot. x Trts.	1107	12	92.3	2.61	1.95	2.96
Error (2)	1910	54	35.4			
TOTAL	6075					

LSD at 5% level of significance = 5.24

LSD at 1% level of significance = 7.07

TABLE 9

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

RESISTANCE FACTOR FOR 2ND INCH OF SURFACE SOIL
AND ANALYSIS OF VARIANCE
September 1953.

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	K	4	10	8	8	30
	G	4	15	4	12	35
	S	9	27	8	14	58
	M	36	36	21	31	124
	DC	36	27	23	31	117
	IC	15	21	24	21	81
	D	26	34	18	26	104
		130	170	106	143	549
B	K	3	4	5	5	17
	G	8	21	10	7	46
	S	18	10	16	11	55
	M	24	24	9	14	71
	DC	12	25	23	19	79
	IC	10	17	19	16	62
	D	14	17	7	9	47
		89	118	89	81	377
C	K	5	10	7	3	25
	G	3	3	4	9	19
	S	9	9	27	7	52
	M	7	15	23	5	50
	DC	25	10	30	15	80
	IC	6	28	34	28	96
	D	6	15	33	15	69
		61	90	158	82	391
		280	378	353	306	1317

TABLE 9 (cont'd.)

ANALYSIS OF VARIANCE FOR RESISTANCE FACTOR FOR 2ND INCH OF SURFACE SOIL

Treatments		Average	
K	72	K	6
G	100	G	8.3
S	165	S	13.8
M	245	M	20.4
DC	276	DC	23.0
IC	239	IC	19.9
D	220	D	18.3
	1317		

Source of Variation	SS	DF	MS	F
Reps.	281	3	93.6	
Rotations	652	2	326	2.2
Error (1)	893	6	149	
Trts.	3030	6	505	15.8
Rot. x Trts.	986	12	82	2.5
Error (2)	1739	54	32	
T O T A L	7581			

LSD at 5% level of significance = 4.6

LSD at 1% level of significance = 6.2

TABLE 10

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

RESISTANCE FACTOR FOR 3RD INCH OF SURFACE SOIL
AND ANALYSIS OF VARIANCE
September 1953

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	K	12*	36	19	11	78
	G	16	23	9	24	72
	S	14	32	14	22	82
	M	36	36	27	36	135
	DC	36	36	30	36	138
	IC	33	30	28	30	121
	D	28	36	24	29	117
		175	229	151	188	743
B	K	3	5	8	10	26
	G	14	30	11	11	66
	S	19	24	20	30	93
	M	30	32	13	31	106
	DC	20	31	23	27	101
	IC	12	22	32	20	86
	D	16	22	12	24	74
		114	166	119	153	552
C	K	7	18	19	3	47
	G	12	9	7	14	42
	S	14	21	29	9	73
	M	8	21	31	9	69
	DC	20	17	30	22	89
	IC	4	30	33	36	103
	D	8	15	36	23	82
		73	131	185	116	505
		362	526	455	457	1800

* The figures in the table are per cent relative tension.

TABLE 10 (cont'd.)

ANALYSIS OF VARIANCE FOR RESISTANCE FACTOR FOR 3RD INCH SURFACE SOIL

September-1953

Treatment		Average	
K	151	K	12.6
G	180	G	15.0
S	248	S	20.7
M	310	M	25.8
DC	328	DC	27.3
IC	310	IC	25.8
D	273	D	22.8
	1800		

Source of Variation	SS	DF	MS	F
Reps.	647	3	215.6	1.3
Rotations	1135	2	567.5	3.39**
Error (1)	1005	6	167.5	
Trts.	2347	6	391.1	9.5**
Rot. x Trts.	671	12	55.9	1.4
Error (2)	2228	54	41.3	
TOTAL	8033	83		

LSD at 5% level of significance = 5.2

LSD at 1% level of significance = 7.0

TABLE 11

SOIL AMENDMENT PLOTS

AGGREGATE ANALYSIS 1953
AND ANALYSIS OF VARIANCE
Mean Weight Diameters

Rotation	Treatments	Rep. I.	II.	III.	IV.	Rot. x Trt.
A	S	.27	.13	.23	.12	.75
	K	.35	.40	.42	.27	1.44
	G	.23	.22	.25	.22	.92
	M	.20	.20	.24	.23	.87
	DC	.24	.20	.22	.26	.92
	IC	.22	.15	.25	.16	.78
	D	.13	.24	.23	.13	.73
		1.64	1.54	1.84	1.39	6.41
B	S	.24	.23	.21	.20	.88
	K	.30	.45	.41	.40	1.56
	G	.23	.21	.26	.22	.92
	M	.16	.20	.21	.29	.86
	DC	.23	.18	.24	.27	.92
	IC	.17	.27	.27	.20	.91
	D	.23	.22	.27	.22	.94
		1.56	1.76	1.87	1.80	6.99
C	S	.21	.23	.29	.21	.94
	K	.35	.41	.38	.43	1.57
	G	.24	.19	.24	.28	.95
	M	.24	.24	.23	.19	.90
	DC	.29	.18	.22	.22	.91
	IC	.30	.24	.23	.20	.97
	D	.19	.22	.22	.20	.83
		1.82	1.71	1.81	1.73	7.07
		5.02	5.01	5.52	4.92	20.47

TABLE 11 (cont'd.)

ANALYSIS OF VARIANCE FOR MEAN WEIGHT DIAMETER

Treatments		Average (cm.)	
S	2.57	S	.21
K	4.57	K	.38
G	2.79	G	.23
M	2.63	M	.22
DC	2.75	DC	.23
IC	2.66	IC	.22
D	2.50	D	.21
	20.47		

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	106	3	35.3	1.37		
Rotation	93	2	46.5	1.80		
Error (1)	135	6	25.8			
Trts.	2682	6	447	26.61**	2.29	3.18
Rot. x Trt.	87	12	7.2	.43		
Error (2)	.0907	54	16.8			
	.4010					

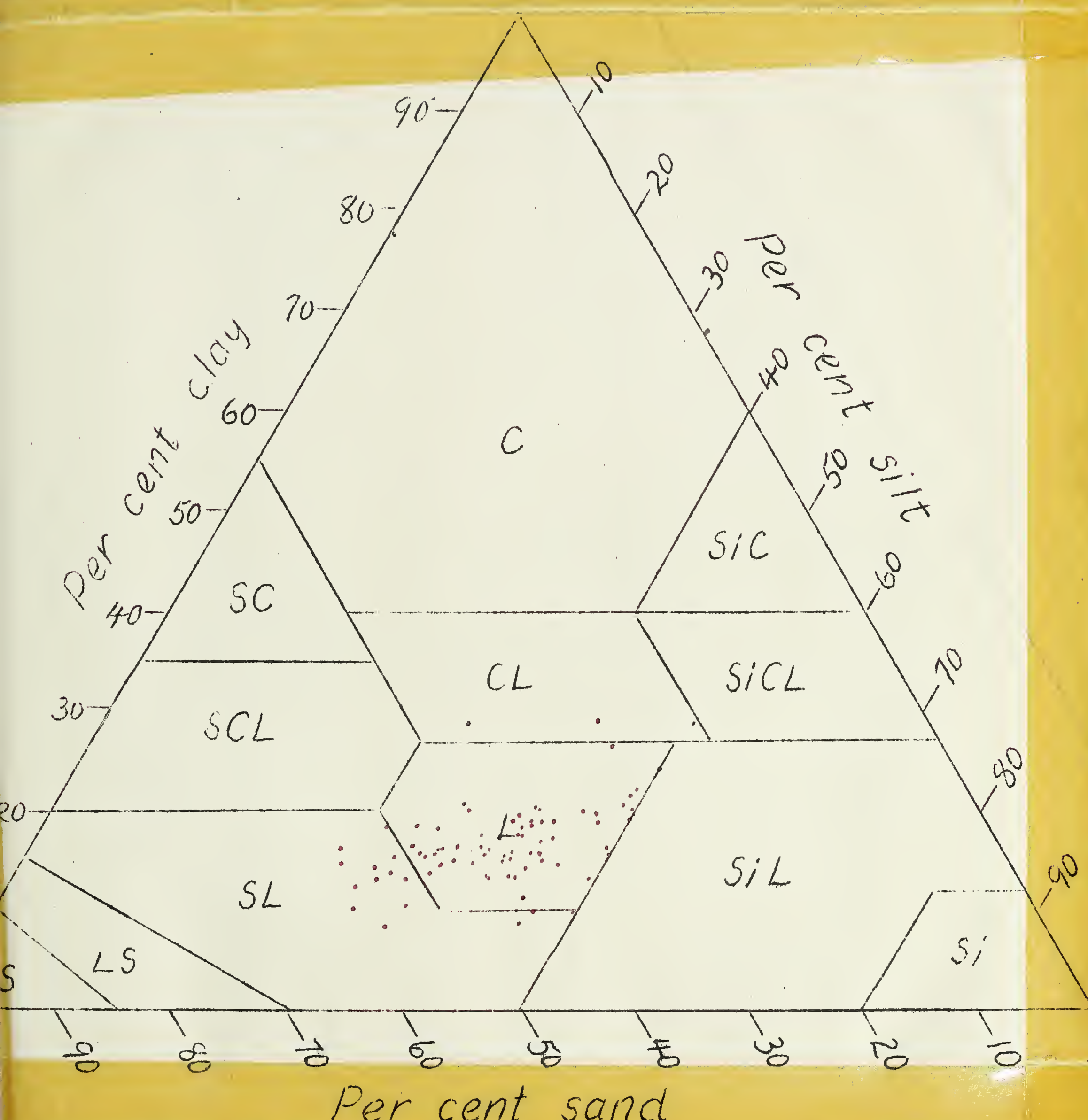
LSD at 5% level of significance = .036

LSD at 1% level of significance = .048

PLATE XIV

YOUNGSTOWN PLOTS

MECHANICAL ANALYSIS OF SURFACE SOIL FROM EACH PLOT



XV

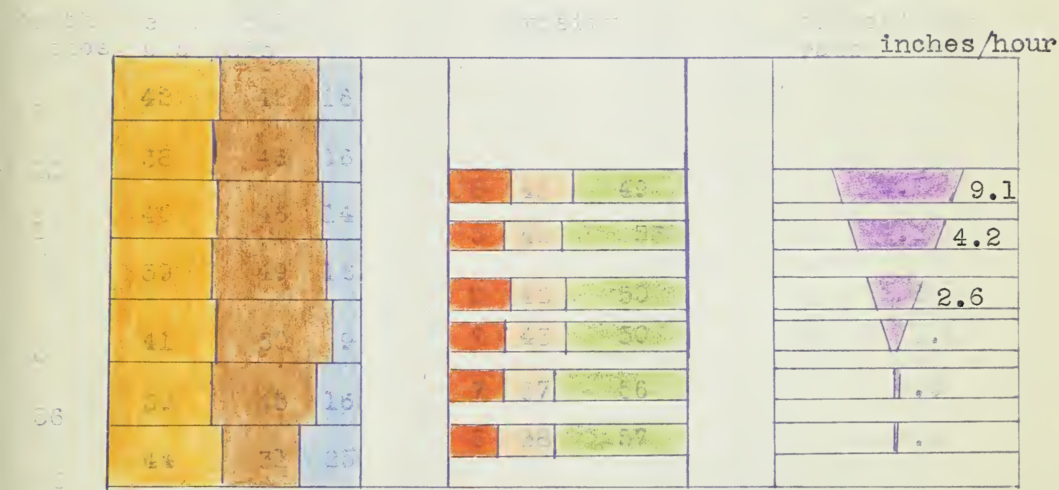


TABLE 12

SOLUBLE SALTS IN SEVERAL PROFILE SOIL

SAMPLES FROM YOUNGSTOWN PLOTS

Range	Plot	Depth	Conductivity mm hos/ cm.	% N.V.S.	Soluble salts (%) HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+
I	1	0"- 6"	.33	.11						
		6"-12"	.41	.15	.116	.006	.09			.027
		12"-18"	.23	.07						
		18"-24"	2.33	.99	.027		1.53	.212	.025	.031
		24"-30"	1.91	.81	.021	.006	1.03	.110	.025	.058
		30"-36"	2.15	.92	.034	.002	1.38	.095	.041	.078
		36"-42"	1.69	.72	.054	.002	.71	.067	.002	.114
		42"-48"	1.91	.81	.051	.004	1.08	.044	.012	.128
	8	0"- 6"	1.32	.54	.114	.006	.57	.060	.010	.061
		6"-12"	.74	.29			.38			.077
		12"-18"	2.98	1.29	.048	-	.74	.139	.034	.169
		18"-24"	3.23	1.39	.026	.002	.78	.144	.033	.192
		24"-30"	3.23	1.39	.031	.002	.80	.154	.032	.199
		30"-36"	2.86	.78	.024	.002	.79	.137	.024	.181
		36"-42"	3.77	1.62	.024	-	.96	.230	.036	.185
		42"-48"	3.60	1.56	.012	.002	.82	.236	.033	
	15	0"- 6"	.37	.13						
		6"-12"	1.72	.73	.046	-	.35	tr.	tr.	.171
		12"-18"	4.84	2.11	.044	-	1.39	.178	.053	.370
		18"-24"	3.37	1.45	.026	-	.83	.111	.034	.250
		24"-30"	3.23	1.39	.036	-	.71	.041	.017	.304
		30"-36"	3.44	1.48	.039	-	.60	.046	.022	.268
		36"-42"	5.00	2.18	.029	-	1.49	.226	.042	.371
		42"-48"	4.94	2.16	.017	-	1.43	.176	.047	.378
II	3	0"- 6"	.27	.09		-				
		6"-12"	.51	.19	.041	.012	.07			.049
		12"-18"	1.41	.59	.068	.002	.35			.148
		18"-24"	3.90	1.69	.024	.002	1.25	.210	.046	.186
		24"-30"	2.70	1.16	.034	.002	.71	.093	.027	.195
		30"-36"	2.13	.91	.034	-	1.00	.062	.018	.160
		36"-42"	1.97	.84	.034	.002	.53	.106	.015	.101
		42"-48"	.61	.23	.122	.004	.09			.138
	10	0"- 6"	.21	.07						
		6"-12"	.41	.15			.04			.051
		12"-18"	1.95	.83	.017		.45	.063	.027	.122

[illegible]

TABLE 12 (cont'd.)

SOLUBLE SALTS IN SEVERAL PROFILE SOIL

SAMPLES FROM YOUNGSTOWN PLOTS

Range	Plot	Depth	Conductivity mm hos/ cm.	% N.V.S.	Soluble salts (%) HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+
II	10	18"-24"	2.57	1.10	.056		.40	.130	.033	.126
		24"-30"	2.07	.87	.048	.002	.51	.071	.032	.115
		30"-36"	2.70	1.16	.034	.002	.65	.172	.035	.120
		36"-42"	3.23	1.39	.026		.90	.218	.039	.125
		42"-48"	3.37	1.45	.046	.002	.82	.248	.034	.119
	17	0"- 6"	.17	.03						
		6"-12"	.75	.30	.002		.01			.005
		12"-18"	.21	.08						
		18"-24"	.15	.05						
		24"-30"	.18	.06						
		30"-36"	.23	.09						
		36"-42"	.20	.07						
		42"-48"	.38	.14						
III	5	0"- 6"	.27	.09						
		6"-12"	.27	.09						
		12"-18"	.58	.22	.081	.002	.05			.076
		18"-24"	1.71	.73	.051	.002	.35	.046	.013	.177
		24"-30"	1.84	.78	.048	.002	.40	.035	.014	.144
		30"-36"	2.49	1.07	.036	.004	.58	.085	.023	.144
		36"-42"	3.37	1.45	.021		.96	.220	.030	.146
		42"-48"	.74	.30	.102	.002	.12			.072
	12	0"- 6"	.40	.14	.026	.004	.01			.041
		6"-12"	4.04	1.74	.026		1.25	.097	.047	.305
		12"-18"	4.62	2.03	.034	.002	1.45	.180	.055	
		18"-24"	3.94	1.70	.039	.004	1.18	.153	.044	.240
		24"-30"	3.23	1.39	.044	.002	.75	.056	.032	.280
		30"-36"	4.15	1.78	.034	.002	1.09	.170	.044	.285
		36"-42"	3.76	1.62	.044		.94	.123	.036	.255
		42"-48"	3.37	1.45	.041		.88	.075	.029	.260
	19	0"- 6"	2.94	1.28	.017	.002	.74	.154	.033	.135
		6"-12"								
		12"-18"	3.68	1.58	.054	.002	.08	.056	.026	.261
		18"-24"	2.49	1.07	.056	.002	.67	.020	.014	.244
		24"-30"	3.59	1.56	.039	.004	.90	.125	.030	.265
		30"-36"	4.15	1.79	.026	.004	.84	.183	.028	.310

TABLE 12 (cont'd.)

SOLUBLE SALTS IN SEVERAL PROFILE SOIL

SAMPLES FROM YOUNGSTOWN PLOTS

Range	Plot	Depth	Conductivity mm hos/cm.	% N.V.S.	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+
					Soluble salts (%)					
III	19	36"-42"-	2.31	.99	.044	.004	.48	.045	.014	.160
		42"-48"	2.23	1.01	.044	.002	.49	.049	.017	.165
IV	7	0"- 6"	.19	.03						
		6"-12"	.29	.09						
		12"-18"	.19	.03						
		18"-24"	-							
		24"-30"	-							
		30"-36"	.34	.11						
		36"-42"	.50	.19	.075	.008	.08			.049
		42"-48"	.61	.23	.048	.012	.08			.064
	14	0"- 6"	.46	.15	.012	.010	.02			.017
		6"-12"	.40	.14	.088	.002	.02			.039
		12"-18"	.45	.15	.066		.05			.047
		18"-24"	.81	.31	.066	.006	.93			.074
		24"-30"	.72	.28	.063	.006	.09			.076
		30"-36"	3.30	1.42	.041	.036	.85	.178	.051	.159
		36"-42"	3.76	1.62	.034	.004	1.01	.248	.051	.151
		42"-48"	3.94	1.70	.054	.012	1.13	.244	.053	.180
	21	0"- 6"	.33	.11						
		6"-12"	.32	.11						
		12"-18"	.28	.09						
		18"-24"	.98	.40	.078	.008	.15			.086
		24"-30"	1.24	.51	.080	.006	.28			.118
		30"-36"	1.38	.56	.063	.004	.26	.005	.008	.120
		36"-42"	1.47	.61	.071	.002	.44	.005	.007	.135
		42"-48"	2.10	.90	.051	.002	.96	.029	.026	.164

NOTE: % N.U.S. were determined by interpolating conductivity readings from a graph on which conductivity and per cent non volatile salts of many samples were plotted in the Soils lab.

Where the conductivity was below .4 mm.hos./cm. no soluble salt determinations were made.

TABLE 13

TOTAL NITROGEN DETERMINATION OF SOME YOUNGSTOWN PLOT SOILS

Sample	% N (oven-dry basis)	% O.M. (N x 20)
Range I - Plot 5	.108	2.16
Range II - Plot 20	.181	3.62
Range III - Plot 8	.203	4.06
Range IV - Plot 8	.177	3.54
Range IV - Plot 19	.107	2.14

DISCUSSION

The field and laboratory studies all indicate one distinct feature - great variability in the physical properties and chemical composition of surface and sub-surface soils within a small area.

There is no doubt that native vegetation reflects soil characteristics and the Youngstown plots are a good example. Thus it may be noted that the buckbrush patches had good permeable profiles and consequent grain yields were good. On the contrary the sparse growth on the eroded pits indicated adverse factors were at work, and here were found poor surface tilth and very low permeability. Grass and sage areas gave average grain yields.

The barley and wheat data indicate that some of the soil amendments used tended to increase yields, and penetrometer and soil aggregate analyses show that a few had a beneficial effect on soil structure. The soil variation however, tended to mask the effects of treatments on crop yield. The second crop year was much more favourable than the first, and effects of soil amendments began to show. Eventually it is possible that plot borders will be visually recognizable by the treatment effects. Generally, krilium, sulphur and gypsum treatments increased yields and improved

soil structure. The magnitude of the increase however fell far short of justifying the expenditure required in applying the amendments. Only under a much more intensive cropping system would such an outlay for soil amendments be practical.

The resistance factor for the first three inches of surface soil was significantly lowest for the gypsum, krilium and sulphur treatments while only the krilium treatments gave a significantly higher mean weight diameter for stable soil aggregates. The September isoprobes showed a greater average depth for these three treatments compared with the remaining treatments. Assessment of these facts is difficult with only one year's data. The importance of the various cultural practices and the effects of the soil amendments will probably not appear for several years.

Some treatments gave unexpected results. There seemed to be a depressed yield with increased rates of krilium. In 1952 the krilium @ 1000 lbs./acre gave a higher barley yield than the krilium @ 2000 lbs./acre treatment, though this difference was not significant. However, in 1953 the gypsum treatment, applied and sampled on the remaining portion of the krilium @ 1000 lbs./acre plot gave a significant yield increase over the krilium @ 2000 lbs./acre. One would have been tempted to rate the krilium treatment as the best since this treatment improved the physical condition of the soil. Another unexpected result was the effect of deep cultivation,

which one might have expected to reduce the resistance to the probe on the penetrometer. Deep cultivation treatment on the contrary gave a high resistance factor for the surface soil. This however might have been predicted since, due to circumstances, the deep cultivation treatment was done in the spring when the moisture content was high. Soil puddling resulted. This effect was also demonstrated by the low September isoprobe average..

The effects of irrigation and treatments on the physical structure of solodized solonetz soils is noticeable in the June and September isoprobe averages (Table 5). Attention is drawn to the varying depth of individual isoprobes illustrated in Plate XVI and XIX. The June isoprobe averages indicate that the depth of isoprobes varied in a uniform manner, as no significant difference was evident between treatments. The krilium, sulphur, and gypsum treatments have a significantly lower isoprobe average than the other treatments in September. This is important since it portrays their beneficial effect on soil structure. Looking at the plot profile diagram again, attention is drawn to plots where the September isoprobes were much lower than the June isoprobes. Theoretically, this increasing depth of isoprobes is the expected future results. There was a decrease in the average depth of September isoprobes compared with the June averages. The soil seemed to harden in layers

as the same resistance was encountered at different and varying depths in some plots. In the fall, the surface soil in some plots was so hard that it was impossible to push the penetrometer probe through the crust. No doubt the greater depth of June isoprobes was due to a higher soil moisture content and possibly winter effects on the soil structure. It will be interesting to compare future penetrometer readings with the 1950 isoprobes.

The mechanical analyses indicate a higher amount of sand in the surface and subsurface soils than one would expect in a soil with such a low percolation rate. The eroded pit profile shows an increase in clay content with decreasing permeability rates, and also shows a high sodium content in the profile. The permeable profile, on the other hand, shows practically no change in the sand and the clay content while the content of soluble salts is negligible.

There is also a high amount of calcium and sulphates in the eroded pit profile. The predominant salts in the profile in water wells of the area are sodium and calcium sulphates. The presence of calcium sulphate in the subsoil is an aid to soil reclamation particularly where this gypsum is close enough to the surface to be brought up and mixed with the surface soil by deep ploughing. This is currently

being tried out in other plots at the test site. Deep rooted plants may also bring back to the surface substantial amounts of calcium.

The high conductivity of certain profiles and the high percentage of non-volatile salts shows clearly the salinity problem. The addition of chemical amendments to lower the exchangeable sodium salts, and provision for drainage, are measures that are necessary to make such soil productive.

The color and depth of the surface soil is generally indicative of fertility. Based on these features, and the nitrogen determinations, the Hemaruka soil would not be classified as a highly fertile soil. It is, no doubt, like other Alberta soils low in phosphorus. The value, however, of commercial fertilizers must for some time be a secondary problem in these soils where heterogenity and poor physical characteristics dominate the crop picture.

Sweet clover growth was not advanced enough in 1953 to show any effects in soil structure or soil fertility, but no doubt in time, beneficial effects will be noticed. A fertility program including the use of legume crops is certainly advocated.

Great variations in the chemical composition and physical properties of the soil was noticed. It is suggested that this heterogeneity can be changed only by a mixing of

surface and subsoil. This mixing would be achieved in part by the large scale levelling under an irrigation program. This levelling would result in soil homogeneity and better physical and chemical properties.

While some soil amendments have improved the physical and chemical properties of the soil, the cost of application is important. Krilium is not economically practical on a field basis; sulphur and gypsum are much cheaper to apply. It seems that an improvement program based on sound cultural practices inter-related with the application of chemical amendments and good crop rotations would be the most practical and permanent method of reclaiming solodized solonetz soils under irrigation. There is no doubt in the writer's mind that Hemaruka soils are irrigable, but at the same time it is recognized that they are poor soils requiring a great deal of very specialized attention before qualifying as good irrigable land.

CONCLUSIONS

The Youngstown plots show great variations in the physical and chemical properties of the Hemaruka soils. This soil variation masked the effects of plot treatments during the first year. During the second year some of the treatments proved of some value. However the plots are still too young to draw sound conclusions.

Field and laboratory studies did reveal certain physical properties and treatment effects. The average depth of September isoprobes was less than the average June depth. The krilium, sulphur and gypsum treatments improved soil structure, as denoted by a lower resistance to penetrometer probe penetration and a significantly deeper isoprobe value in September over the remaining treatments. The manure and deep cultivation treatments did not improve the soil structure. All treatments gave significantly higher yields over the dry check in 1953 while no difference was noted in 1952.

Compared with the irrigated check however, only sulphur, manure and gypsum treatments gave significant increases in 1953.

Permeability studies showed that a large amount of sodium in the profile was responsible for very low permeability

rates. Solodized solonetz soils illustrate the close connection between the physical properties of a soil and the chemical composition of the adsorbing complex.

The presence of calcium sulphate in the subsoil will no doubt be of value in reclaiming solodized solonetz soils in this area. The variation of soils in texture, fertility and in physical behaviour in a small area is of practical importance. The writer feels that solodized solonetz soils would be greatly improved if the soil could be mixed thoroughly as by deep ploughing or by levelling operations for irrigation.

There is no doubt in the writer's mind that Hemaruka soils are irrigable providing drainage is assured. It is also recognized that they are poor soils and would require a great deal of very specialized attention before qualifying as good irrigable land.

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APPENDIX

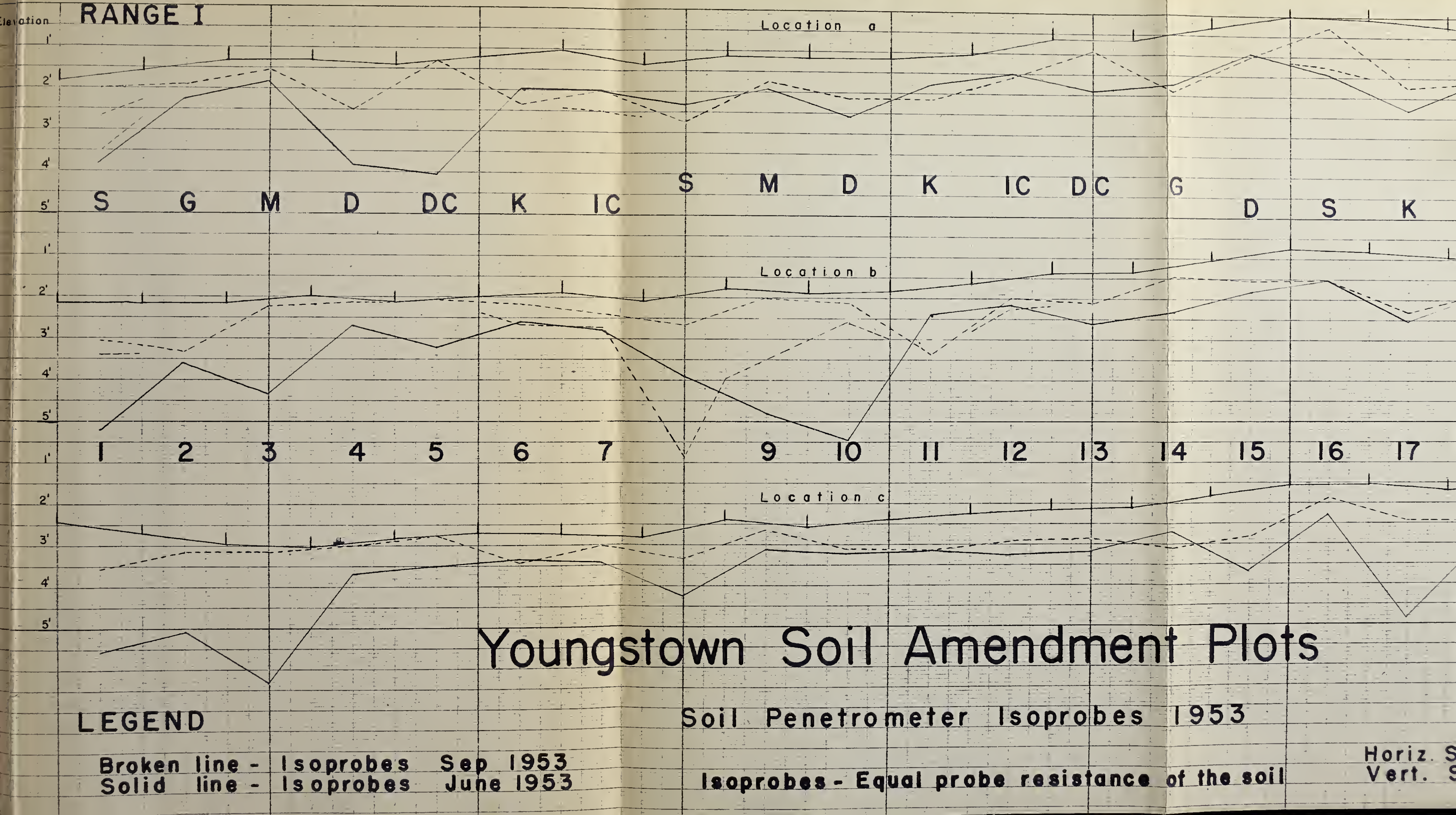
TABLE 14

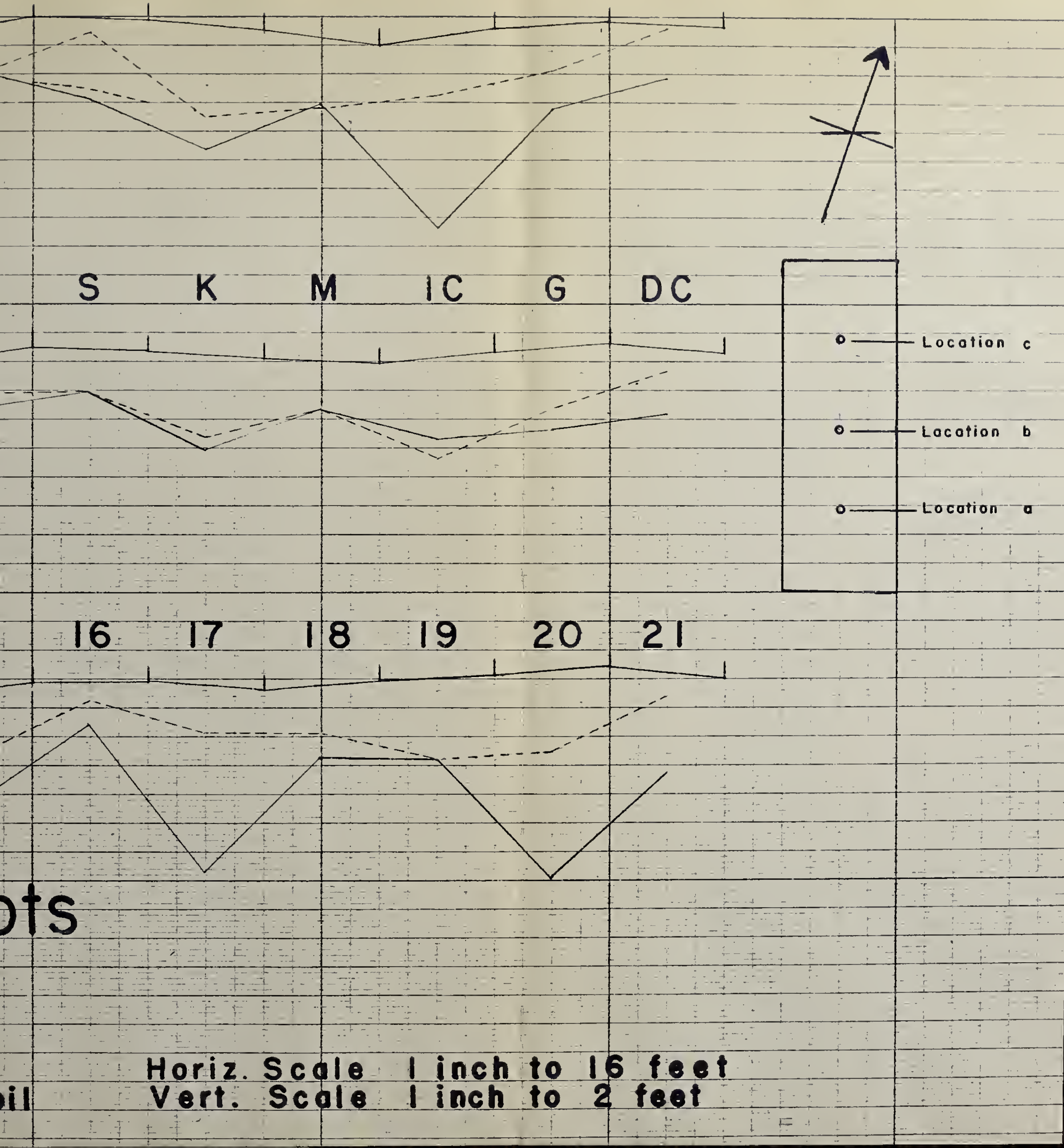
General
Geological Formations in Alberta

System	Formations	Origin	Materials and Remarks
Tertiary	Paskapoo	Continental	sandstone, shale conglomerate siliceous limestone
Upper Cretaceous	Edmonton St. Mary River	Continental	gray, bentonitic sandstones and shale: grey, greenish and carbonaceous shale.
	Bearpaw	Marine	grey, brown, and green shale, in part bentonitic. Bentonite: limy concretions grey glauconitic sandstone.
	Belly River Series Pale beds	Continental	Bentonite sandstone, grey, yellow and dark shale.
	Foremost	Continental	Light, grey, sandstone, shale
	Pakowki	Marine	Dark shale, some sandy bed.
	Milk River	Continental	sandstone and sandy shale.
	Alberta shale	Marine	Dark shale, sandy shale: sandstone and pebble.

APPENDIX

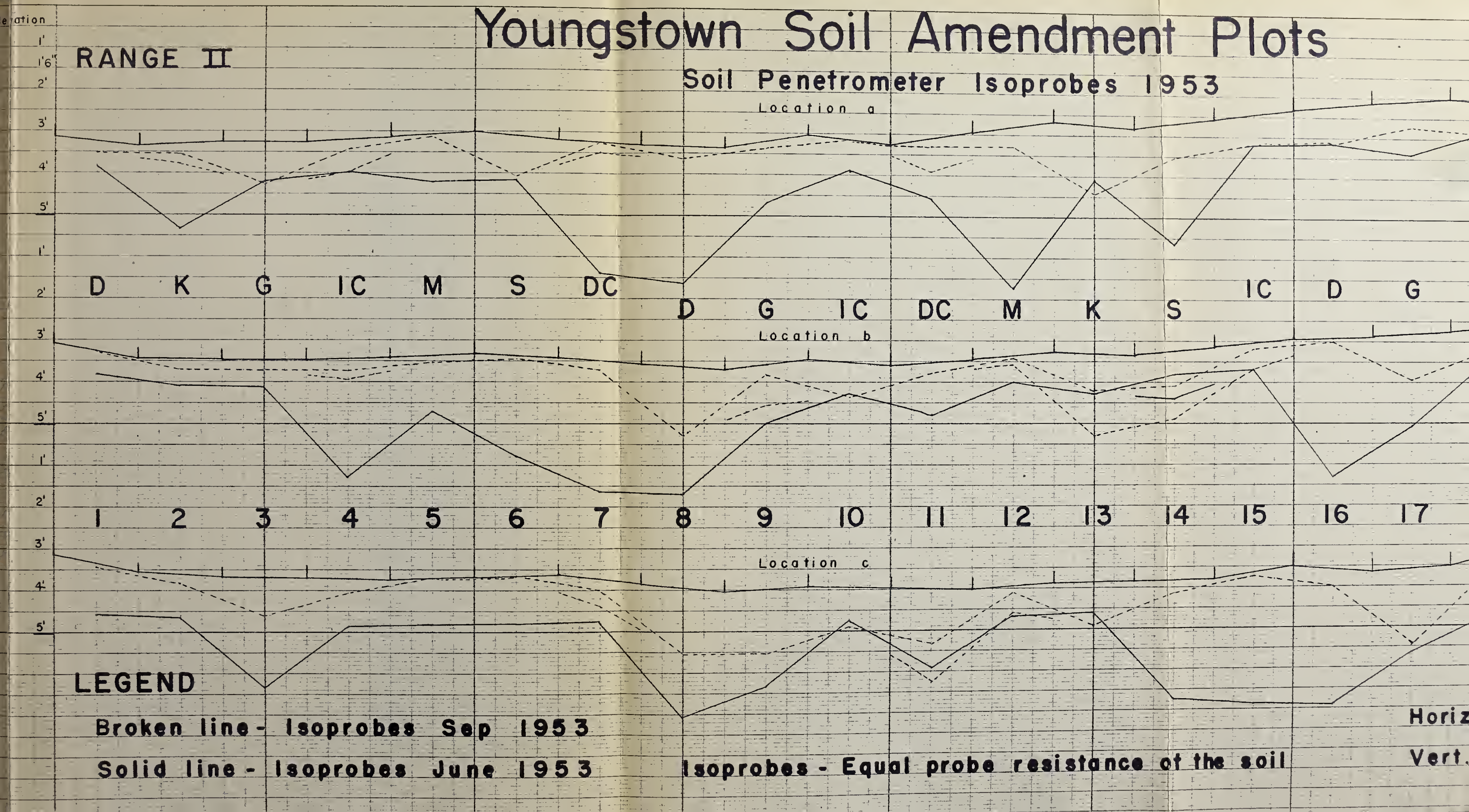
PLATE XVI




S K M IC G DC
Location c
Location b
Location a
16 17 18 19 20 21
ots
Horiz. Scale 1 inch to 16 feet
il
Vert. Scale 1 inch to 2 feet

APPENDIX

PLATE XVII



ts

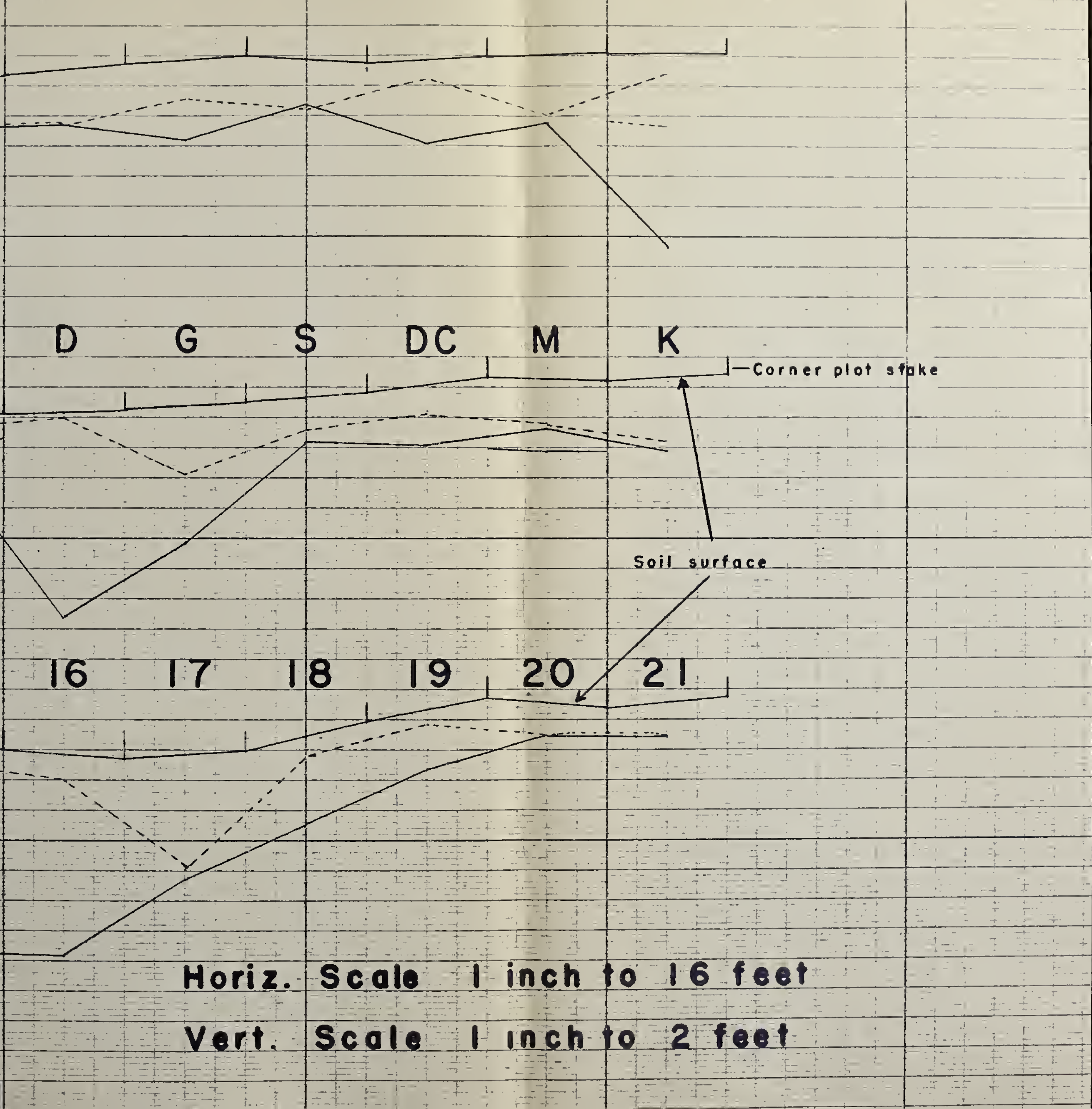
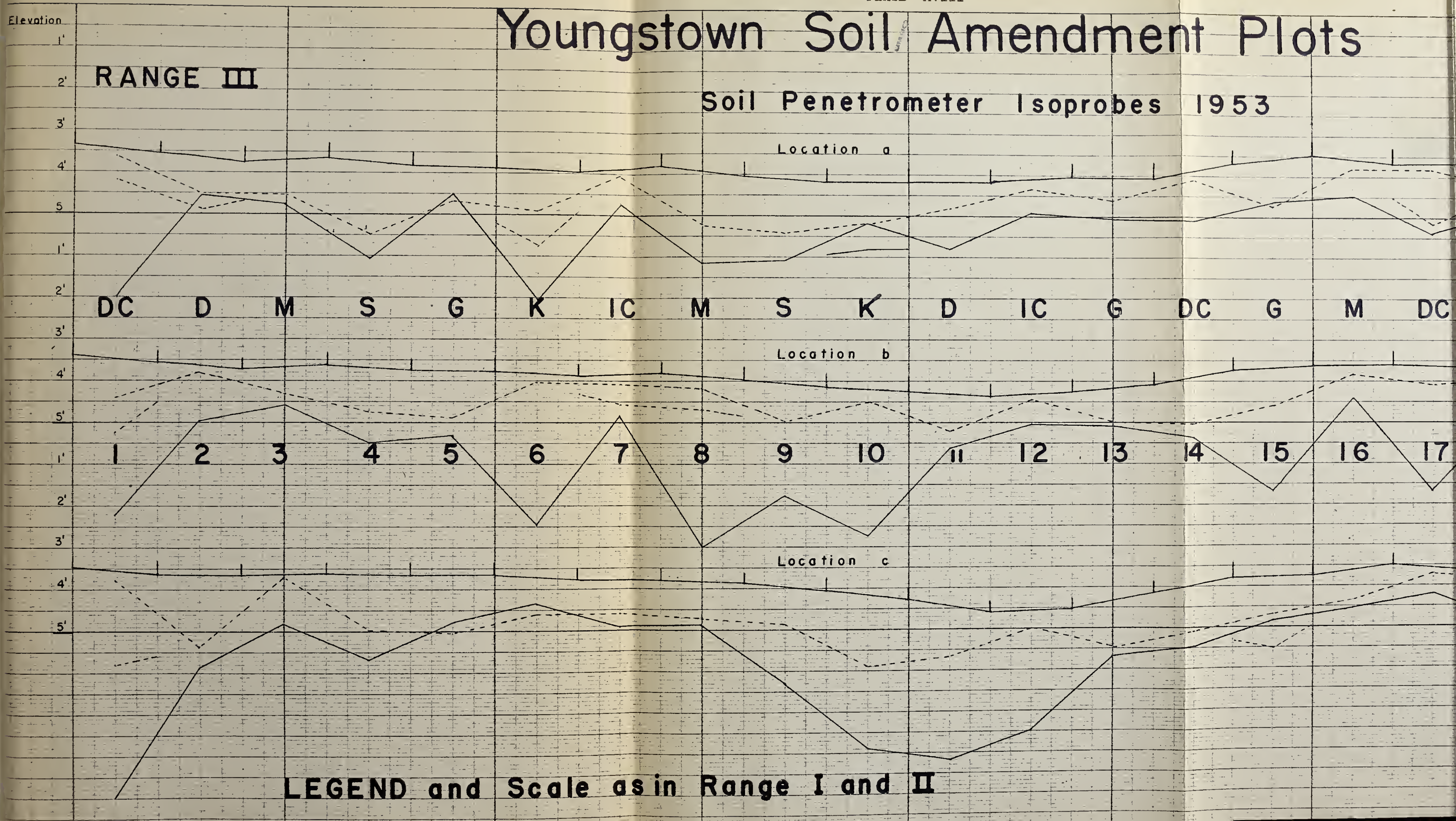
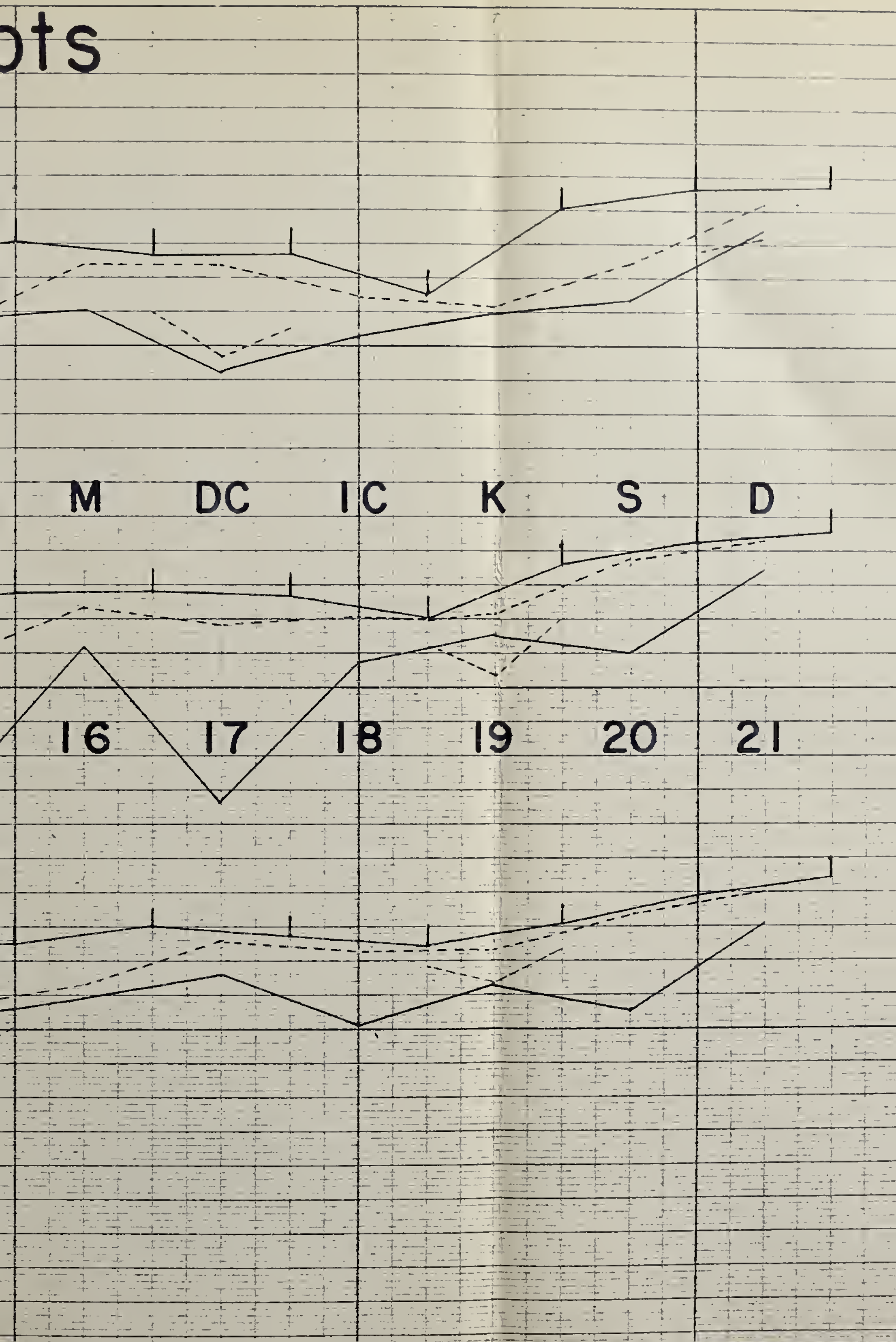

D G S DC M K
Corner plot stake
Soil surface
16 17 18 19 20 21
Horiz. Scale 1 inch to 16 feet
Vert. Scale 1 inch to 2 feet

PLATE XVIII


Youngstown Soil Amendment Plots
RANGE III
Soil Penetrometer Isoprobes 1953
Elevation
1'
2'
3'
4'
5'
Location a
DC D M S G K IC M S K D IC G DC G M DC
Location b
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Location c
LEGEND and Scale as in Range I and II



ots
M DC IC K S D
16 17 18 19 20 21

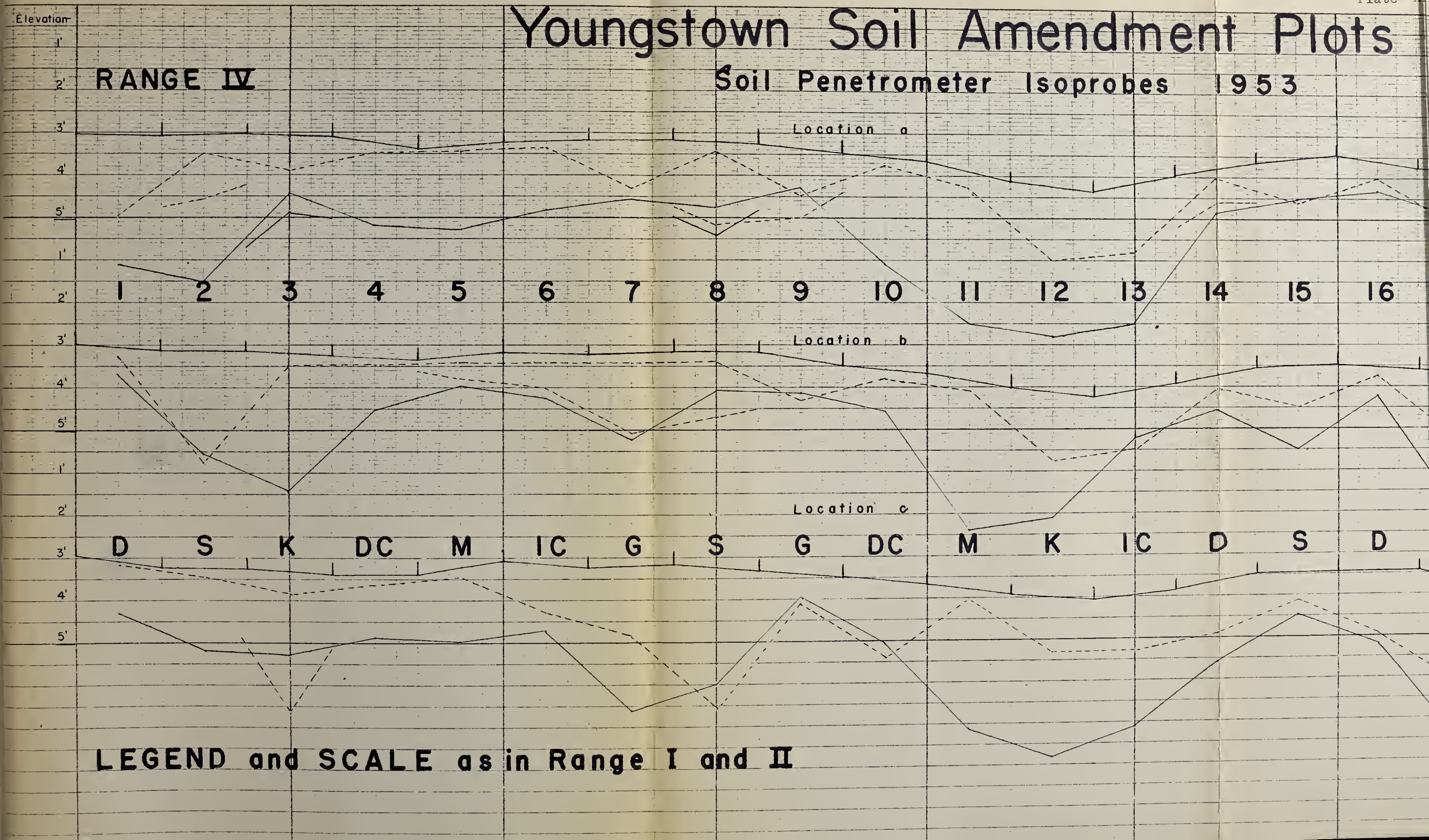

Youngstown Soil Amendment Plots
RANGE IV
Soil Penetrometer Isoprobes 1953
Elevation
1'
2'
3'
4'
5'
Location a
Location b
Location c
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
D S K DC M IC G S G DC M K IC D S D
LEGEND and SCALE as in Range I and II

Plate XIX